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TEST OF T53-L-13 ENGINE (S/N LE-14083).(U)
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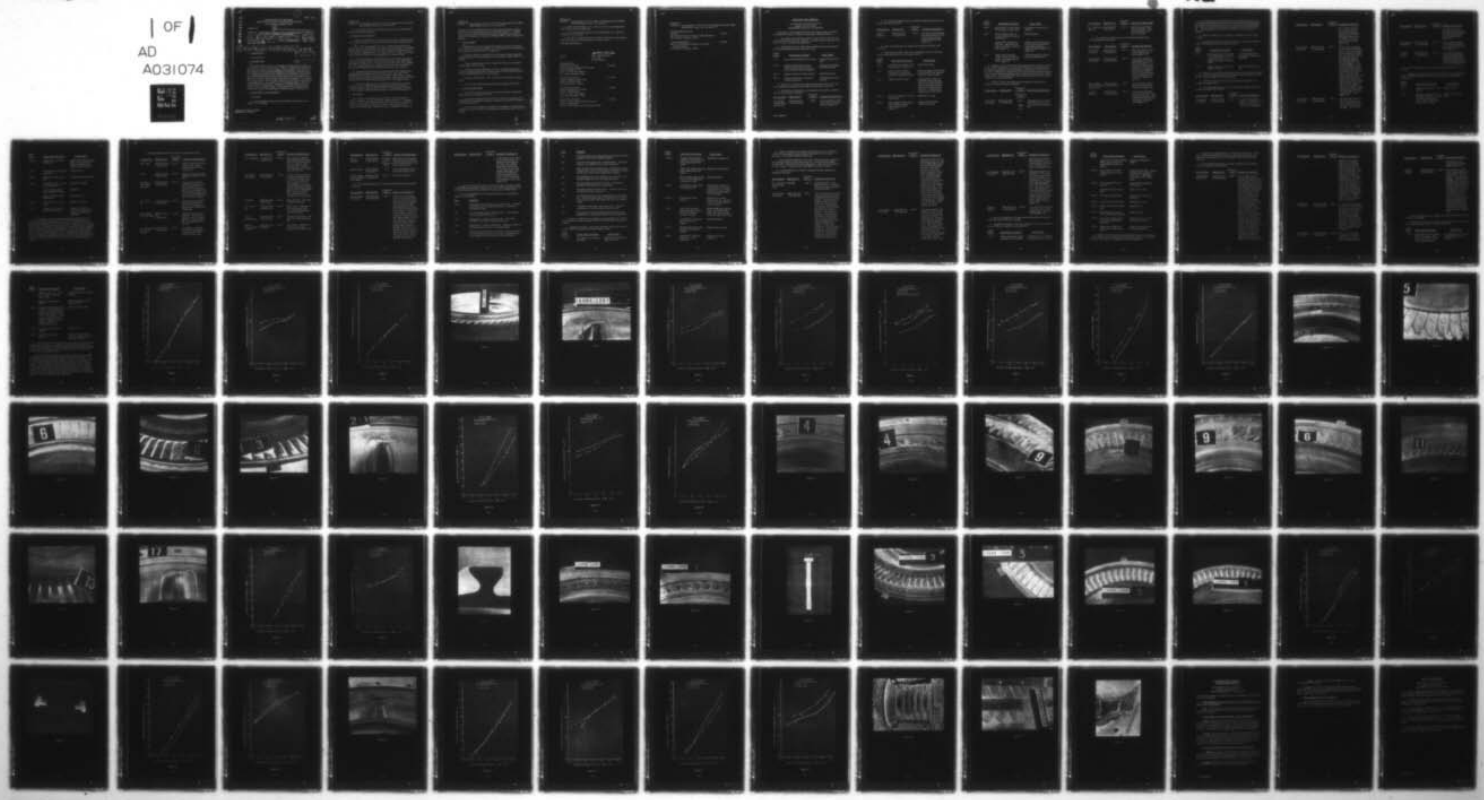

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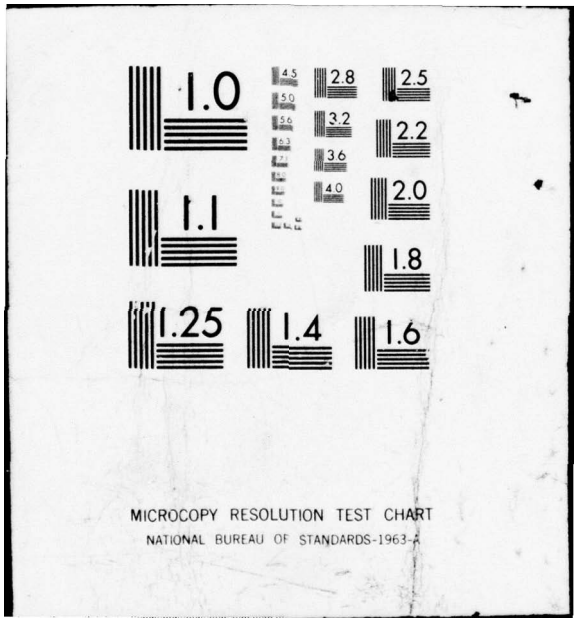
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DEPARTMENT OF THE ARMY
UNITED STATES ARMY AVIATION TEST BOARD
Fort Rucker, Alabama 36360

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(6) SUBJECT: Letter Report of Test of T53-L-13 Engine (S/N LE-14083). USATECOM Project No. 4-6-0150-05

(9) Letter Rept. (11) 19 Nov 68 (12) 78 P.

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(16) USATECOM-4-6-0150-05

1. REFERENCES

See Inclosure 3.

2. BACKGROUND

Development of the T53-L-13 engine is a major product improvement effort for UH-1( ) helicopters. Phase F logistical evaluation test of production models of these engines was directed by US Army Test and Evaluation Command (USATECOM) on 8 February 1966 (reference 1). Testing of this engine was initiated by the US Army Aviation Test Board (USAAVNTBD) in January 1967 and has been continuous since that time. Subject engine was the high-time test engine in the program when in July 1968, a fourth-stage compressor disc failure occurred at 1,946 flight hours. As a result, the Commanding General, US Army Aviation Materiel Command, requested a "chronological summary letter report on subject engine, to include history of operation and maintenance performed, and failure analysis report" (reference 5).

3. OBJECTIVE OF THIS REPORT

To provide:

a. A chronological summary of the results of test of T53-L-13 engine, S/N LE-14083.

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b. Conclusions and recommendations which can be formulated as a result of this test program.

4. SUMMARY OF RESULTS

a. History of operation, maintenance performed, and failure analysis of subject engine are chronologically summarized in Inclosure 1.

b. At 1,199.3 operating hours, the 36-blade second-stage compressor disc was removed due to cracks in the disc tenons. A 34-blade second-stage compressor disc was then installed and operated 747.4 hours prior to engine failure. The engine failure at 1,946.7 operating hours was due to failure of the fourth-stage compressor disc.

c. The major problem evident during the six hot-end inspections (300-hour intervals) was circumferential cracking of the first-stage gas-producer (GP) nozzle. A cast first-stage GP nozzle was installed at 1,199.3 engine hours, but testing of this nozzle was insufficient to warrant consideration of an extended hot-end inspection interval.

d. Approximately 750 hours of testing indicate that Engineering Change Proposals (ECP's) LY-GT-123R, -139, -148, and -153 (paragraph 4f, Inclosure 1) are recommended modifications. Insufficient testing or lack of information precludes conclusions with respect to other ECP's incorporated at approximately 1,200 engine hours.

e. Several components were successfully operated for varying numbers of hours with damage exceeding the limits specified in Technical Bulletin (TB) 55-2800-200-30/1, indicating that the limits can be extended. (Recommended changes are listed in Inclosure 2.)

5. DISCUSSION

The criteria for defining the time between overhaul (TBO) of T53-L-13 engines is to use four basic engines operated to a common number of hours as samples (reference 2). Operation of the subject engine demonstrated an 1,800-hour life with the exception of the second- and fourth-stage compressor discs. Significant compressor

problems occurring during this test clearly demonstrate the requirement for major improvement prior to any TBO extension. Testing (747.4 hours) of the 34-blade second-stage compressor disc was insufficient to validate the existing 1,200-hour TBO on that configuration engine.

6. CONCLUSIONS

a. Inspections of fourth-stage discs which have operated beyond the 1,200-hour level in test engines are required prior to consideration of an increase in TBO of T53-L-13 engines.

b. Further testing is required on the 34-blade second-stage disc configuration prior to consideration of an increase in TBO of T53-L-13 engines.

c. Major improvements in the compressor discs are required to increase their service life.

d. Damage limits pertaining to the first- and second-stage GP nozzles, the first-stage power-turbine nozzle, and the exhaust diffuser in TB 55-2800-200-30/1 are too restrictive.

e. ECP's LY-GT-123R, -139, -148, and -153 should be incorporated.

f. The hot-end inspection interval should remain at 300 hours.

7. RECOMMENDATIONS

a. No further TBO extensions be made until further testing indicates that such extensions are valid.

b. The fourth-stage disc of the T53-L-13 TBO test engines at the USAAVNTBD be debladed, stripped, and liquid dye-penetrant inspected at 1,500 disc hours.

c. The Project Manager investigate the feasibility of improving the compressor discs to enhance the operational suitability of the T53-L-13 engine.

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d. ECP's LY-GT-123R, -139, -148, and -153 in the configuration tested in this engine be approved.

e. The recommended changes to TB 55-2800-200-30/1, shown in Inclosure 2, be approved.

f. The hot-end inspection interval remain at 300 hours until further testing indicates an increased interval would be valid.

FOR THE PRESIDENT:

A. J. Montcalmo

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A. J. MONTCALMO
1LT, AGC
Acting Adjutant

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DETAILED TEST RESULTS

Letter Report of Test of T53-L-13
Engine, S/N LE-14083
USATECOM Project No. 4-6-0150-05

Following is a chronological history of the subject engine relative to maintenance actions, analytical inspections, and performance.

1. The engine was installed on UH-1H, S/N 66-1094, when the aircraft arrived at Fort Rucker, Alabama. It entered test in January 1967 with 16.5 hours' previous operating time.

a. Maintenance actions, other than scheduled, that occurred prior to the first analytical hot-end inspection were:

Engine Hours	Fault and/or Remarks	Action Taken
111.1	Power turbine (N_2) governor stuck.	Adjusted linear actuator.
150.8	Standard (field-type) hot-end inspection performed at direction of Iroquois Project Manager.	Inspection completed; No parts replaced.
262.9	Engine electrical harness frayed.	Replaced harness.
300.0	Engine due 300-hour analytical hot-end inspection.	Removed engine from aircraft.

b. Figures 1, 2, and 3 show engine performance prior to the 300-hour inspection compared to performance at the start of the test.

c. The 300-hour analytical hot-end inspection resulted in replacement of the following component:

Nomenclature	FSN and P/N	Component Hours	Reason for Replacement
First-Stage Gas-Producer (GP) Nozzle	2840-975-0258 1-110-520-14B	300.0	Circumferential cracking in outer shroud aft of vanes (figure 4).

d. The following component was reinstalled although damage exceeded the published TB limits:

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
Exhaust Diffuser	2840-925-5467 1-150-240-01E	300.0	5/8-inch crack extending circumferentially across weld in outer strut at outboard leading edge (figure 5).

2. After the inspection, the engine was installed in UH-1H, S/N 63-15524.

a. Maintenance actions, other than scheduled, that occurred prior to the second analytical hot-end inspection were:

Engine Hours	Fault and/or Remarks	Action Taken
300.0	Left-hand rear engine mount bearing worn excessively.	Replaced bearing.
316.1	UH-1H, S/N 63-15524, scheduled for temporary transfer to another location.	Removed engine from UH-1H, S/N 63-15524, and installed in UH-1H, S/N 66-1094.
453.1	Engine would not start.	Checked igniter plug and found OK. Replaced inoperative start fuel solenoid valve and electrical cable because of broken cannon plug wire. Replaced two clogged start fuel nozzles.
469.9	Oil leaks around No. 2 bearing housing.	Replaced "0" ring.
488.9	Engine exhaust gas temperature (EGT) increased approximately 15°C. (figure 6).	Replaced flow divider (troubleshooting).

Engine Hours	Fault and/or Remarks	Action Taken
498.9	Replacement of flow divider had no effect on EGT rise.	Continued to monitor EGT closely.
544.9	All four igniter plugs in excess of technical manual (TM) limits.	Replaced plugs.
	Engine EGT continued to increase. Approximately 30°C. increase in referred EGT (figure 7).	Engine cleaned by ingestion of cleaning compound while motoring compressor. Referred EGT dropped 10°C. (figure 8).
557.3	Engine EGT continued rising. Referred EGT increase now approximately 35°C. (figure 9).	Removed engine for analytical hot-end inspection.

b. Figures 9, 10, and 11 show engine performance prior to removal at 557.3 hours compared to performance subsequent to reassembly after the 300-hour analytical hot-end inspection. It should be noted that the increases in EGT were evident only when EGT was referred and compared to the referred EGT immediately after reassembly of the engine at 300.0 engine hours. The indicated EGT observed by the pilots in no way alerted them to an increase in EGT.

c. The 557.3-hour analytical hot-end inspection resulted in replacement of the following components:

Nomenclature	FSN and P/N	Component Hours	Reason for Replacement
		Nozzle Less Curl	
First-Stage GP Nozzle	2840-975-0258 1-110-520-14M	407.3	190 degrees of circumferential cracking in outer shroud aft of vanes (figure 12).
		Curl	
		257.3	

Nomenclature	FSN and P/N	Component Hours	Reason for Replacement
No. 2 Bearing Aft Seal	2840-944-7293 1-300-356-01	557.3	Seal deteriorated with pieces missing. Heavy carbon deposit on aft face of bearing.

d. The following components were reinstalled although damage exceeded published TB limits:

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
First-Stage GP Rotor	2840-924-8647 1-100-880-01C	557.3	Blade tip rub up to 3/64 inch at leading edge of blades (figure 13).
Second-Stage GP Nozzle	2840-925-9665 1-120-000-06D	557.3	Two cracks extending completely across inner shroud with up to 1/2 inch of cracking in vane brazement. Both inner shroud cracks extended into the front support 7/32 to 3/8 inch and into the aft support 5/32 to 13/32 inch (figures 14 and 15).
Second-Stage Power-Turbine (PT) Nozzle	2840-943-2382 1-140-470-05E	557.3	Two 5/8-inch cracks in inner shroud and vane brazements (figure 16).
Exhaust Diffuser	2840-925-5467 1-150-240-01E	557.3	Two cracks extending across two struts at outboard leading edge. Both extended across weld and measured 1/2 and 3/4 inch (figure 17).

e. The increase in referred EGT was symptomatic of the severe circumferential cracking in the first-stage GP nozzle and the associated tip rubbing of the first-stage GP rotor. It should be emphasized again that the rise in EGT was not evident to the pilot. Only by referring the EG and comparing it to a baseline EGT did the increase become apparent.

3. After the inspection, the engine was installed in UH-1H, S/N 66-1093.

a. Maintenance actions, other than scheduled, that occurred prior to the third analytical hot-end inspection were:

Engine Hours	Fault and/or Remarks	Action taken
591.3	Governor surged excessively at 98-99% N_1 above 3,000 feet mean sea level (m.s.l.). Engine not topped at 100% N_1 speed.	Aircraft test flown by maintenance officer and found OK.
616.9	Engine topped at 97% N_1 and 42 p.s.i. torque.	Adjusted military trim 1%.

b. Figures 18, 19, and 20 show engine performance prior to removal at 897.3 hours compared to performance subsequent to reassembly after the 557.3-hour analytical hot-end inspection.

c. The 897.3-hour analytical hot-end inspection resulted in no component replacements.

d. The following components were reinstalled although damage exceeded the published TB limits:

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
First-Stage GP Nozzle	2840-975-0258 1-110-520-14D	340.1	Two circumferential cracks, 3 1/2 and 4 inches, in channel inboard of vanes on aft side (figure

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
			21). Cracks extended into the outer shroud from the trailing edge brazement of 15 vanes circumferentially up to a distance of 3/8 inch into the outer shroud (figure 22).
Second-Stage GP Nozzle	2840-925-9665 1-120-000-06D	897.3	Three cracks extending across inner shroud with up to 1/2 inch of cracking in vane brazement (figure 23). Two of these cracks extended into both the front and aft supports. One extended only into the front support. The cracks extended between 7/32 and 25/32 inch into the forward inner support and between 3/8 and 1/2 inch into the aft inner support (figures 24 and 25), Thirty-nine vanes had brazement cracks extending 5/16 inch in the outer shroud at the leading edge. At 17 vanes, these brazement cracks extended axially up to 5/32 inch into the outer shroud (figure 26).
First-Stage PT Nozzle	2840-944-7296 1-190-000-09C	897.3	All vanes had cracks of up to 7/16 inch in the vane brazements in the outer shroud at the leading edge. At one vane

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
			the brazement crack extended 5/16 inch axially into the outer shroud at the vane leading edge (figure 27).
Second-Stage PT Nozzle	2840-943-2382 1-140-470-05E	897.3	Three cracks extended across the inner shroud 23/32, 23/32, and 11/16 inch (figure 28).
Exhaust Diffuser	2840-925-5467 1-150-240-01E	897.3	Two cracks extended across two struts at the outboard leading edge. Both extended across the weld and measured 27/32 and 3/4 inch (figure 29).

4. After the inspection, the engine was installed in UH-1H, S/N 66-1093.

a. Maintenance actions, other than scheduled, that occurred prior to the 1,200-hour analytical inspection at the engine manufacturer's facility were:

Engine Hours	Faults and/or Remarks	Action Taken
993.9	Tachometer generator seal leaking.	Replaced seal.
999.6	Maximum torque of 42 p.s.i available at 100% N_1, +25°C. outside air temperature (OAT), 550°C. EGT, 300 feet pressure altitude.	Adjusted N_1 1/4 turn down.

Engine Hours	Faults and/or Remarks	Action Taken
1,010.9	Engine goes to 103% N_1 at 50 p.s.i.	Engine retrimmed in accordance with instructions of engine manufacturer's technical representative.
1,057.9	Oil leak at N_2 tachometer generator.	Replaced seal.
1,076.1	Defective starter generator.	Changed starter generator.
1,158.1	Oil leaking at No. 4 bearing scavenge line.	Replaced "0" ring.
	All four igniter plugs worn beyond TM limits.	Replaced.
	Slight oil leak at engine tachometer.	Replaced seal.
1,164.9	Fuel leak at servo fuel filter.	Replaced "0" ring.
1,199.3	Engine due 1,200-hour analytical inspection.	Engine removed and returned to engine manufacturer for analytical inspection.

b. The engine received a complete analytical inspection by the engine manufacturer. In addition, the hot-end was analytically inspected by the USAAVNTBD project engineer. Figures 30 and 31 show engine performance prior to removal at 1,199.3 engine hours compared to performance subsequent to reassembly after the 897.3-hour analytical hot-end inspection. Lycoming Report No. 1519.12.7, under Contract DAAE 11-67-C-0452(3), subject: "T53-L-13 Engine LE-14083 Performance Calibration and Inspection After 1,200 Hours of Field Operation," covers the analytical inspection results in detail. Some parts were reworked, primarily those which had corrosion or damage to protective coating.

c. The parts replaced and the reasons for replacement were:

Nomenclature	FSN and P/N	Component Hours	Reason for Replacement
Face Plate	2840-924-3649 1-030-067-02	1,199.3	Several scratches on seal contact area. Repair method exists but is uneconomical.
Lock	2840-735-6543 1-060-119-01	1,199.3	Replaced with new configuration lock (ECP LY-GT-152).
Accessory Gear Cover Assembly	2840-949-5459 1-080-330-06	1,199.3	Acceptable to overhaul standards; however, part was replaced due to a machine error during rework to incorporate ECP's LY-GT-142 and -148. Assembly, P/N 1-080-330-01, was installed on rebuild.
No. 1 Bearing	3110-727-3032 1-300-015-04	1,199.3	Bearing was serviceable, but was replaced to install a new configuration bearing with an outer race riding cage.
Second-Stage Disc Assembly	FSN not available. 1-100-710-04	1,199.3	Cracks in tenons at five positions. Cracks were similar to those shown in figure 32. New 34-blade disc installed (ECP LY-GT-161).
No. 2 Bearing Housing Assembly	2840-971-6271 1-110-470-05	1,199.3	Acceptable to overhaul standards, but replaced to incorporate ECP's LY-GT-139 and -148.

Nomenclature	FSN and P/N	Component Hours	Reason for Replacement
No. 2 Bearing	3110-863-1237 1-300-013-04	1,199.3	Inner diameter failed to meet blueprint dimension. Heat discloration and end wear on rollers. New bearing, P/N 1-300-175-01, installed to incorporate ECP LY-GT-139.
First-Stage GP Nozzle	2840-975-0258 1-110-520-14	642.0	Cracks in channel at rear of nozzle extended circumferentially through areas of 6 1/2, 8 1/4, and 10 inches (figure 33). Circumferential crack in outer shroud connecting trailing edge of three vanes (figure 34). New cast nozzle, P/N 1-110-520-19, installed (ECP LY-GT-155).
Ring Seal	2840-946-2420 1-300-351-01	1,199.3	Ring collapsed. New standard part installed.
No. 4 Bearing	3110-727-3032 1-300-015-04	1,199.3	Serviceable. Replaced so that bearing with outer race riding configuration could be installed.
Power Turbine Bolt	5306-948-3240 1-140-168-02	1,199.3	Bowed and distorted. Standard bolt installed (figure 35).
Exhaust Thermocouple Harness	6685-963-1115 5469087G5	1,199.3	Serviceable. Replaced to install new 12-point harness (ECP LY-GT-146).

Nomenclature	FSN and P/N	Component Hours	Reason for Replacement
Primer Nozzles	2915-019-5469 1-300-349-02	2 nozzles-1,199.3 2 nozzles-746.2	Replaced all four nozzles. Two nozzles had zero flow and two had less than minimum allowable flow.
Igniter Plugs	2925-957-9947 1-300-348-01	41.2	Two plugs replaced due to broken insulation at pin.
N_1 Accessory-Power-Takeoff Gear Spline	2840-671-0164 1-100-212-01	1,199.3	Excessive backlash.

d. The following parts were reinstalled although damage exceeded TB limits:

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
Second-Stage GP Nozzle	2840-925-9665 1-120-000-06D	1,199.3	Three cracks extending across inner shroud with up to 1/2 inch of cracking in vane brazement (figure 36). All three cracks extended between 3/8 and 11/16 inch into the forward inner support. Two of the cracks extended between 11/16 and 3/4 inch into the aft support (figures 36 and 37). Seventy-five vanes had brazement cracks up to 3/8 inch long at the leading edge in the outer shroud. Twenty-four extended axially into the outer shroud from the leading edge of the vanes, but did not extend over the step onto the vertical face

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
			of the outer shroud. Five of these type cracks extended over the edge of the step at the leading edge of the nozzle up to 11/32 inch from the vane leading edge (figure 38). Three vane brazement cracks extended axially up to 1/2 inch toward the trailing edge of the nozzle (figure 39).

e. At 1,199.3 hours, the first- and second-stage PT nozzles which exceeded TB serviceability criteria at the 897.3-hour inspection met the new field limits which were available to Lycoming and USAAVCOM.

f. The following ECP's were incorporated prior to returning the engine to Fort Rucker:

ECP	SUBJECT
123R	Compressor and impeller housing dowel pins. Changed from taper pins to straight hollow pins. Existing housings reworked.
136	No. 2 bearing housing retaining studs. Two existing screws replaced with studs.
138	Modified flow divider and dump valve. Reworked assembly to accept new seal configuration.
139	Improved No. 2 seal configuration. Required rework of bearing housing and a No. 2 bearing change.
142	Fuel-control drive spline lubrication. Required rework of fuel-control drive gear in accessory gearbox and a new configuration drive spline on the fuel control.

ECP	SUBJECT
146	12-point exhaust gas temperature thermocouple harness. Required rework of the exhaust diffuser.
148	Improved scavenging of No. 2 bearing area. Required rework of air diffuser and accessory gearbox.
151	Short turbine-blade-retention pins. Installation of short retention pins in the second-stage gas-producer turbine, and the first- and second-stage power turbines.
152	Mounting pad lock, inlet housing. Incorporation of new design locking feature on mounting pad plugs.
153	External purge, starting fuel system. Required installation of additional new components.
155	Cast gas-producer turbine nozzle. Replacement of the brazed nozzle with a cast unit.
160	Variable inlet guide vanes, feedback levers, test position. Required replacement of feedback levers on fuel control and variable inlet guide vane with new configuration.
161	34-blade second-stage compressor disc. Required replacement of second-stage compressor disc.
162	Rerouting of variable inlet-guide-vane actuator hoses. Replaced hose assemblies with new hose configuration.

5. After the inspection, the engine was reassembled and returned to Fort Rucker. It was installed in UH-1H, S/N 66-1093, for further testing.

a. Maintenance actions, other than scheduled, that occurred prior to the 1,500-hour analytical hot-end inspection were:

Engine Hours	Faults and/or Remarks	Action Taken
1,277.0	Oil leak at N_2 tachometer generator.	Replaced N_2 tachometer generator seal.

Engine Hours	Faults and/or Remarks	Action Taken
1,292.5	Foreign object damage (FOD) to one blade in first axial stage beyond TM limits.	Replaced one blade set.
	FOD to one blade in second axial stage beyond TM limits.	Replaced one blade set.
	Several blades excessively loose in first-stage axial compressor rotor.	Shimmed blades.
1,329.3	Chip detector light came on during run-up.	Found chips and fuzz on chip detector. No metal found on screens. Cleaned plug and released aircraft for flight.
1,423.9	Chip detector light came on.	Small piece of metal found on screen. Cleaned screens and released aircraft for flight.
1,469.1	Lower left-hand and right-hand igniter plugs burned and chipped around electrodes.	Replaced left-hand igniter plug. Reinstalled right-hand plug, pending availability of replacement plug.
	Two gaskets worn excessively at start fuel fittings.	Replaced gaskets.
1,479.3	Replacement igniter plug available for previous writeup.	Replaced igniter plug.
1,500.7	Engine due 1,500-hour analytical hot-end inspection.	Engine removed for inspection.

b. Figures 40 and 41 show engine performance prior to removal at 1,500.7 hours compared to performance subsequent to reassembly after the 1,199.3-hour analytical inspection.

c. The only parts replaced at the 1,500.7-hour inspection were the two retaining studs on the aft side of the No. 2 bearing housing (ECP LY-GT-136). Both studs had failed (figure 42). They had been installed for 301.4 hours. The same type studs (ECP-136) were installed.

d. The following were reinstalled although damage exceeded the published TB limits:

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
No. 2 Bearing Oil Scavenge Tube	Unknown	301.4	Chafing of tube by combustor deflector. Dimpled deflector to prevent further contact with tube.
Second-Stage GP Nozzle	2840-925-9665 1-120-000-06D	1,500.7	Four cracks in inner shroud vane brazements extended completely across the inner shroud. These cracks extended between 3/32 and 11/16 inch radially down the forward inner support, and between 3/32 and 13/16 inch down the aft inner support. Two cracks of 1/4 and 1/2 inch in inner shroud vane brazements. The 1/2-inch brazement crack extended 3/32 inch into the forward inner support. These type cracks are shown in figures 36 and 37. All vanes had brazement cracks up to 3/8 inch in outer shroud. Forty-three vanes had brazement cracks at the

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
			vanes in the outer shroud extending axially from the vane leading edge toward the nozzle leading edge; however, they did not extend over the step. Seven brazement cracks which extended into the outer shroud extended over the step onto the vertical face of the outer shroud up to 3/8 inch axially from the leading edge of the vane. Two vanes had cracks in the outer shroud and vane brazement of 9/16 and 1 3/16 inch total length. The cracks did not extend completely to the leading or trailing edge. These cracks are shown in figures 38 and 39.
First-Stage PT Nozzle	2840-944-7296 1-190-000-09C	1,500.7	Although damage to this nozzle at 1,199.3 hours met field serviceability criteria available to the manufacturer, such criteria were not available to the USAAVNTBD at the 1,500.7-hour inspection. The damage exceeding available criteria was: All vanes had brazement cracks between 7/16 and 9/16 inch long in the outer shroud. Forty-four of the vanes

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
			had brazement cracks which extended from the leading edge of the vanes up to 1/2 inch into the outer shroud (figure 27).
Second-Stage PT Nozzle	2840-943-2382 1-140-470-05	1,500.7	Although damage to this nozzle at 1,199.3 hours met field serviceability criteria available to the manufacturer, such criteria were not available to the USAAVNTBD at the 1,500.7-hour inspection. The damage exceeding available criteria was: Three cracks extended across the inner shroud radially down the inner support 23/32, 23/32, and 11/16 inch (figure 28).
Exhaust Diffuser	2840-925-5467 1-150-240-01E	1,500.7	Two struts had cracks of 13/16 and 1 inch in the leading edge at the outer shroud (figure 29).

6. After the inspection, the engine was reassembled and installed in UH-1H, S/N 66-1093, for testing.

a. Maintenance actions, other than scheduled, that occurred prior to the 1,800-hour analytical inspection were:

Engine Hours	Faults and/or Remarks	Action Taken
1,521.5	Engine chip detector light and master caution light	Found normal accumulation on magnetic plug. Cleaned

Engine Hours	Faults and/or Remarks	Action Taken
	came on for 5 minutes during flight, then went out for remaining 30 minutes of flight.	plug and reinstalled in engine.
1,545.9	EGT jumps 50° to 100° during run-up at 3-foot hoover.	Checked intake area. Cleaned grass from airframe inlet filter. Tightened loose connection on EGT gauge.
1,545.9	EGT running 50° above normal.	Calibrated and balanced EGT system.
	Leak at fuel control servo filter.	Replaced "0" ring.
1,649.1	Oil leak at N_2 governor.	Replaced oil seal on N_2 governor.
1,660.9	Leak from main fuel filter.	Replaced "0" ring.
1,698.9	Engine oil return line leaking.	Replaced line.
1,719.3	Shroud insulator burned out on all four igniter plugs.	Replaced plugs.
1,765.5	Drive seal leaking and oil blowing through starter-generator.	Replaced drive seal and starter-generator.
1,808.3	Engine due 1,800-hour analytical hot-end inspection.	Engine removed and hot end disassembled.

b. Figures 43 and 44 show engine performance prior to removal at 1,808.3 engine hours compared to performance subsequent to reassembly after the 1,500.7-hour analytical hot-end inspection.

c. No parts were replaced at the 1,808.3-hour inspection. There was a crack in the weld where the No. 2 bearing oil discharge line entered the outer portion of the air diffuser. The crack was weld repaired.

d. The following components, although exceeding the TB limits, were reinstalled for further tests:

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
Second-Stage GP Nozzle	2840-925-9665 1-120-000-06D	1,808.3	Five cracks in inner shroud vane brazements extended completely across inner shroud. The cracks extended between 1/2 and 3/4 inch down the forward inner support and between 3/16 and 1 inch down the aft inner support. Two other cracks existed in the inner shroud vane brazement, extending 3/16 and 9/16 inch down the vane brazement. The 3/16-inch brazement crack extended 3/16 inch into the front inner support. The 9/16-inch brazement crack extended 3/8 inch into the front support and 3/8 inch into the inner shroud toward the trailing edge of the nozzle. These type cracks are shown in figures 36 and 37. All vanes had brazement cracks of up to 3/8 inch in the outer shroud at the leading edge. Forty-three vane brazement cracks extended

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
			into the outer shroud axially at the leading edge of the vanes; however, they did not extend over the step. Ten cracks extended over the edge of the step up to 3/8 inch from the vane leading edge. Two vanes had brazement cracks of 5/16 and 15/16 inch at the inner shroud. Two other vane brazement cracks extended into the outer shroud to both the leading and trailing edges, completely across the outer shroud. (These type cracks are shown in figures 36 and 37.)
First-Stage PT Nozzle	2840-944-7296 1-190-000-09C	1,808.3	All vanes had brazement cracks in the outer shroud. A number of these cracks extended into the outer shroud up to 1/2 inch from the vane leading edge. Four of these extended over the edge of the outer shroud and between 5/32 and 3/8 inch into its vertical face. (These cracks were previously shown in figure 27.)
Second-Stage PT Nozzle	2840-943-2382 1-140-470-05	1,808.3	Four cracks extended completely across the inner shroud. Three of these extended between

Nomenclature	FSN and P/N	Component Hours	Damage Exceeding TB
			21/32 and 3/4 inch radially down the inner support (figure 28).
Exhaust Diffuser	2840-925-5467 1-150-240-01E	1,808.3	Two struts had cracks in the leading edge at the outer shroud. One extended 1 inch circumferentially. The other crack extended 1 1/8 inch circumferentially (figure 29). Another crack, forward of the previous crack and located in the mid cone, extended 1 11/16 inch circumferentially. At the midpoint of this crack, a crack branched 1/4 inch axially to the strut weld and then extended out 1 inch along the strut weld into the mid cone at a 45-degree angle to the strut (figure 45).

7. After the inspection, the engine was reinstalled in UH-1M, S/N 65-9445, for testing.

a. Maintenance actions, other than scheduled, that occurred prior to the engine failure at 1,946.7 engine hours were:

Engine Hours	Faults and/or Remarks	Action Taken
1,817.6	Engine tops out at 98.5% N_1, 45 p.s.i. torque, 590°C. EGT, 23°C. OAT, 3,000 feet pressure altitude.	Increased hi-trim 1/4 turn and adjusted droop compensator.

Engine Hours	Faults and/or Remarks	Action Taken
	100% N_1, 50 p.s.i. torque, 25°C. OAT, 1,000 feet, 560°C. EGT.	Decreased hi-trim a small amount.
	Engine oil temperature 105°C.	Replaced engine oil temperature bulb.
1,850.1	Intermittent torsional effect in hover. At 97-99% N_1 and 610°C., maximum torque available to maintain 6,600 r.p.m. was 38 p.s.i. EGT, torque, and N_1 fluctuated together. Engine oil temperature 100°C. six minutes from start.	Replaced hot air valve.
1,884.8	N_2 tachometer generator leaking.	Replaced seal.
1,946.7	Engine failed during takeoff.	Removed engine and returned to manufacturer for teardown analysis.

b. Figures 46 and 47 show the engine performance just prior to the compressor disc failure as compared to the performance after the 1,808.3-hour inspection. Figures 48 and 49 show the change in engine performance due to use and nozzle change during the 1,839.1 hours of operation at the USAAVNTBD.

c. Inspection at the manufacturer's plant revealed that the engine had experienced a fourth-stage compressor disc tenon failure. All the blades in the fourth and fifth stages were broken at the base. Extensive damage was present in the third-, fourth-, and fifth-stage stators. The centrifugal compressor had extensive damage and the hot-end was burned up. Figure 50 shows the compressor and figure 51 shows the failed tenon. The manufacturer stated that evidence of fatigue and stress corrosion were present and that the N_1 overspeed reported at 1,010.0 engine hours might have contributed to the failures. Figure 52 shows a close-up of the failed tenon.

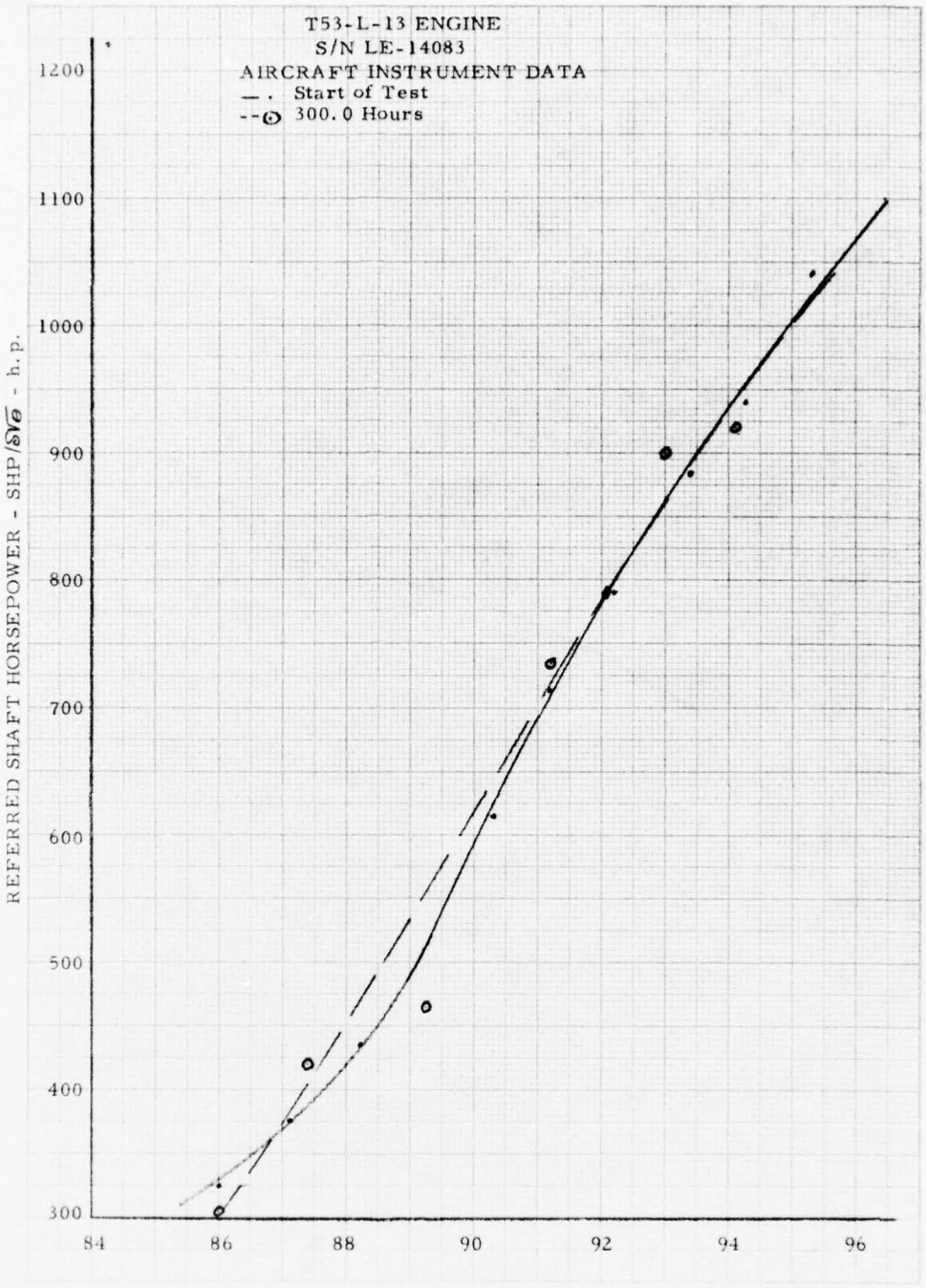
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— . Start of Test
--⊙ 300.0 Hours
REFERRED SHAFT HORSEPOWER - SHP/δ√θ - h.p.
1200
1100
1000
900
800
700
600
500
400
300
84
86
88
90
92
94
96
REFERRED GAS PRODUCER SPEED - N1/√θ - % RPM

Figure 1.

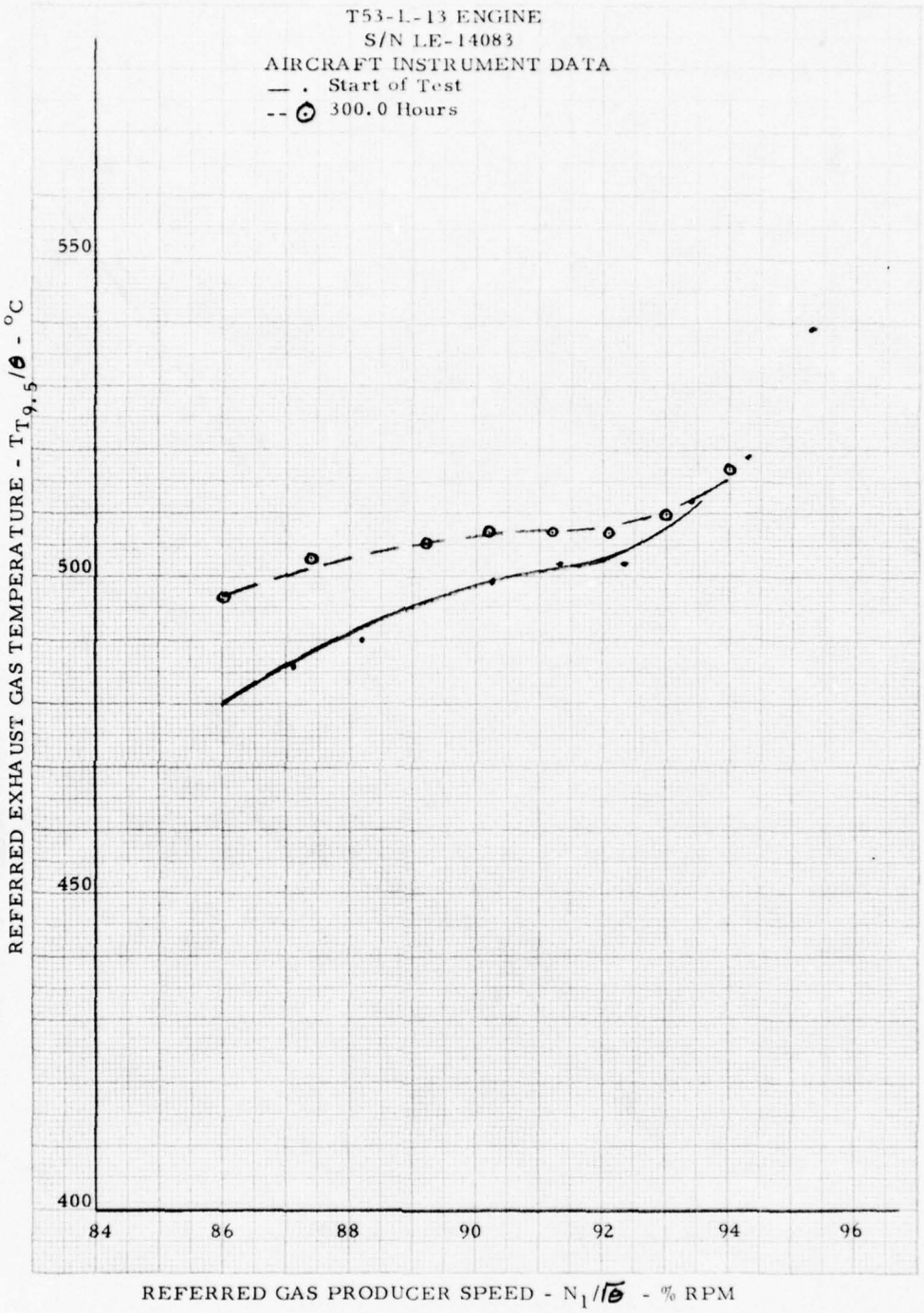
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— . Start of Test
-- ⊙ 300.0 Hours
REFERRED EXHAUST GAS TEMPERATURE - $T_{T9.5}/\theta$ - °C
550
500
450
400
84
86
88
90
92
94
96
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 2.

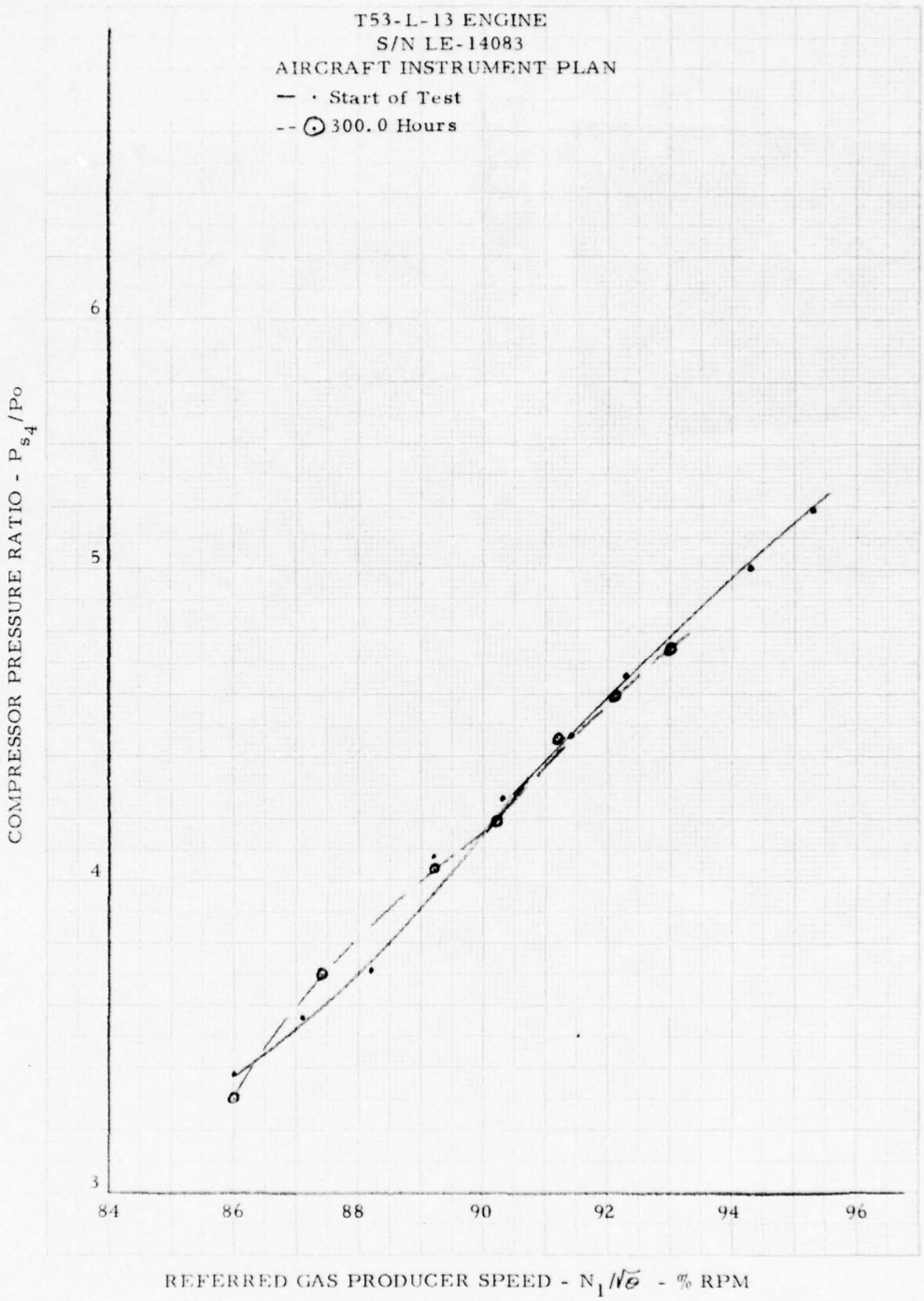
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT PLAN
— · Start of Test
-- ⊙ 300.0 Hours
COMPRESSOR PRESSURE RATIO - P_{s_4}/P_o
6
5
4
3
84
86
88
90
92
94
96
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 3.

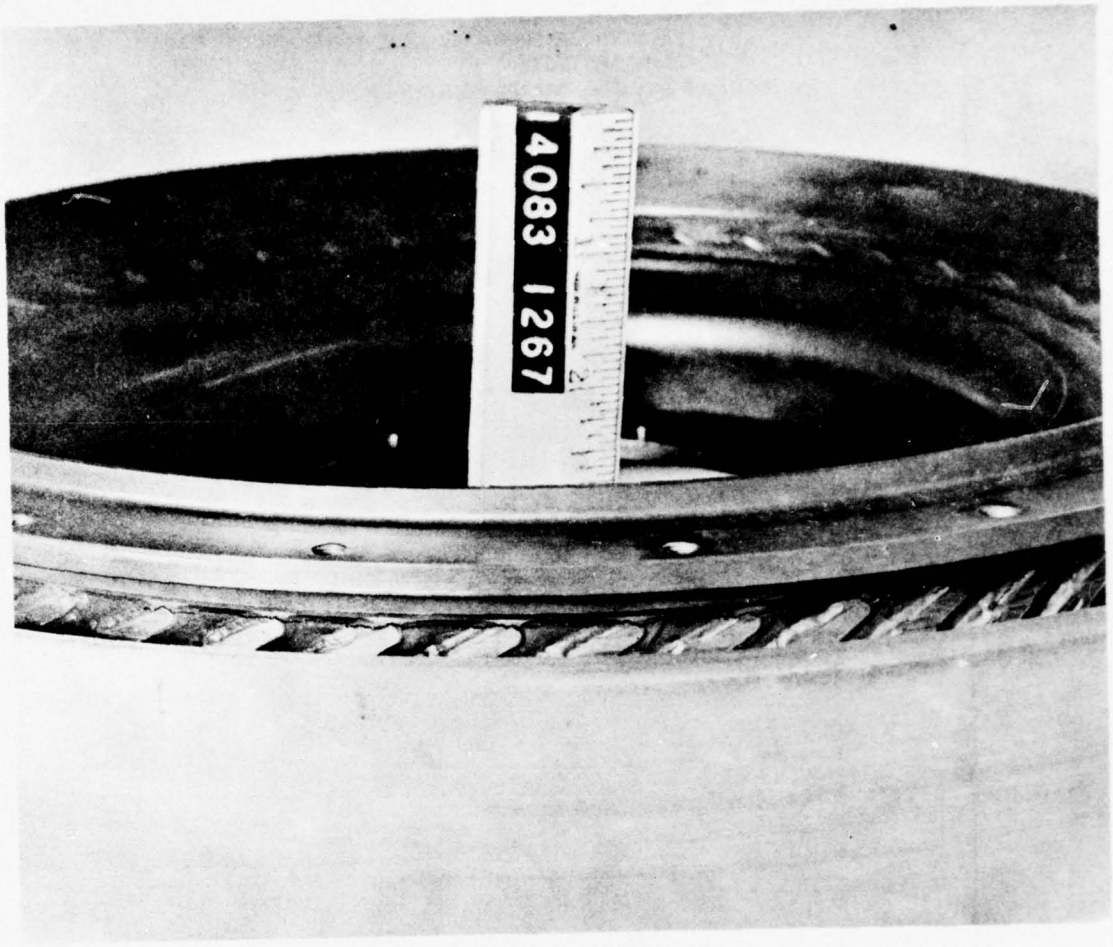

Figure 4.

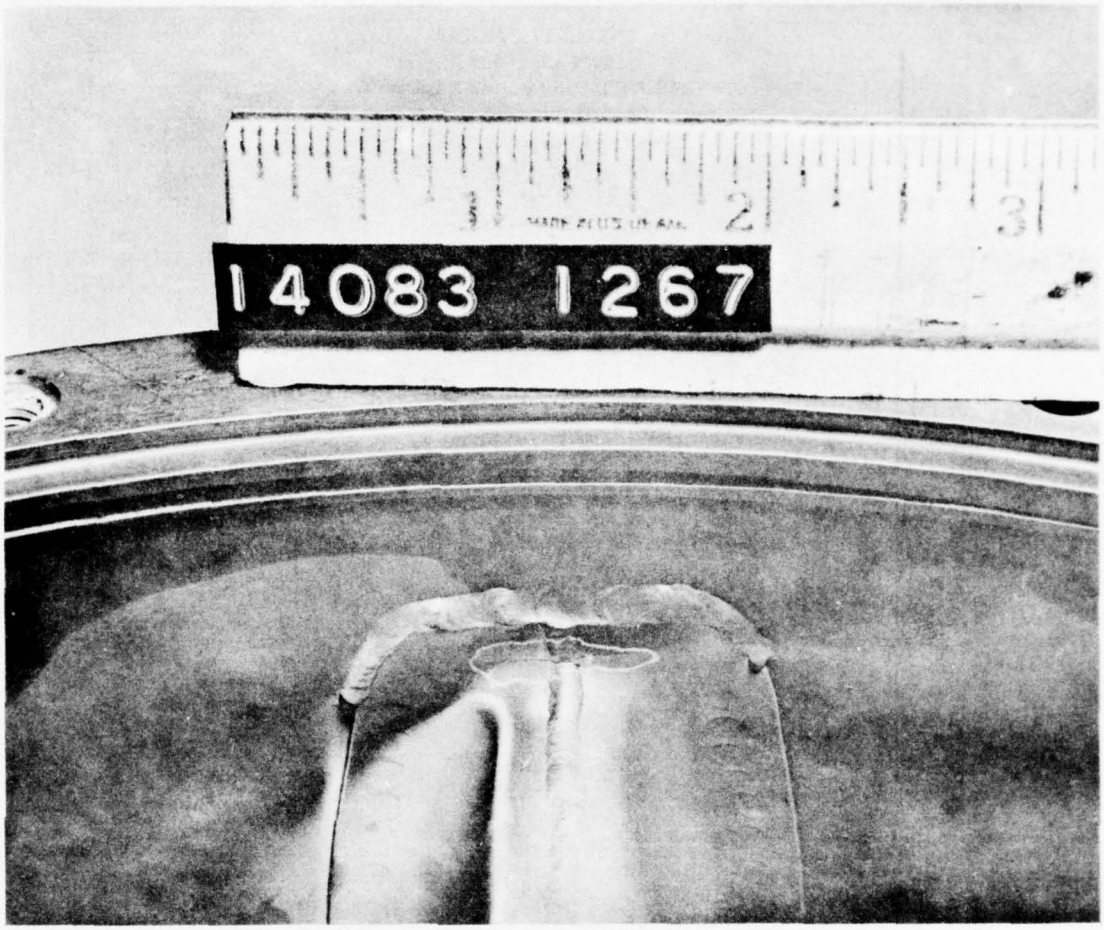

Figure 5.

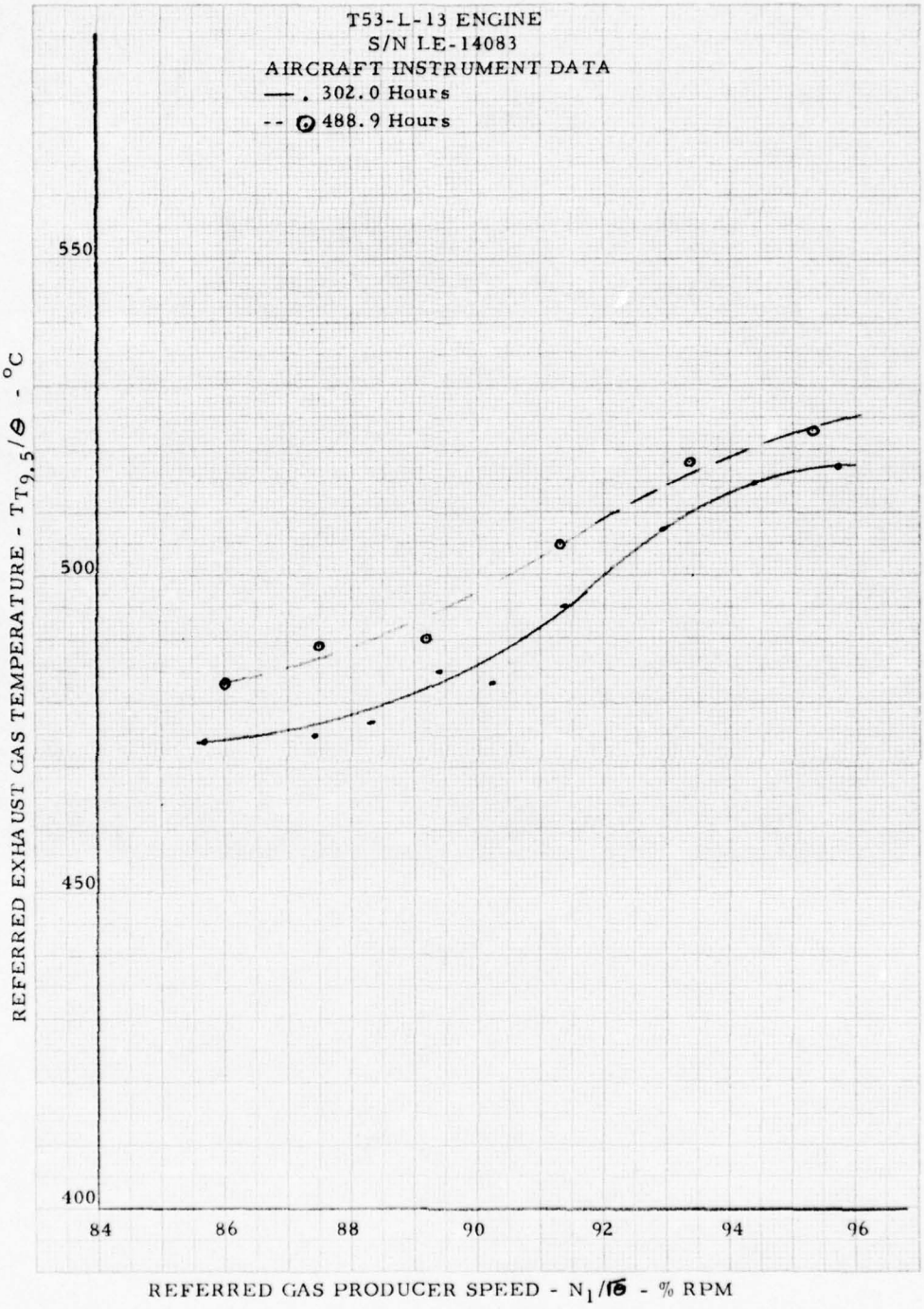
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
302.0 Hours
488.9 Hours
550
500
450
400
84
86
88
90
92
94
96
REFERRED EXHAUST GAS TEMPERATURE - $T_{T9.5}/\theta$ - °C
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 6.

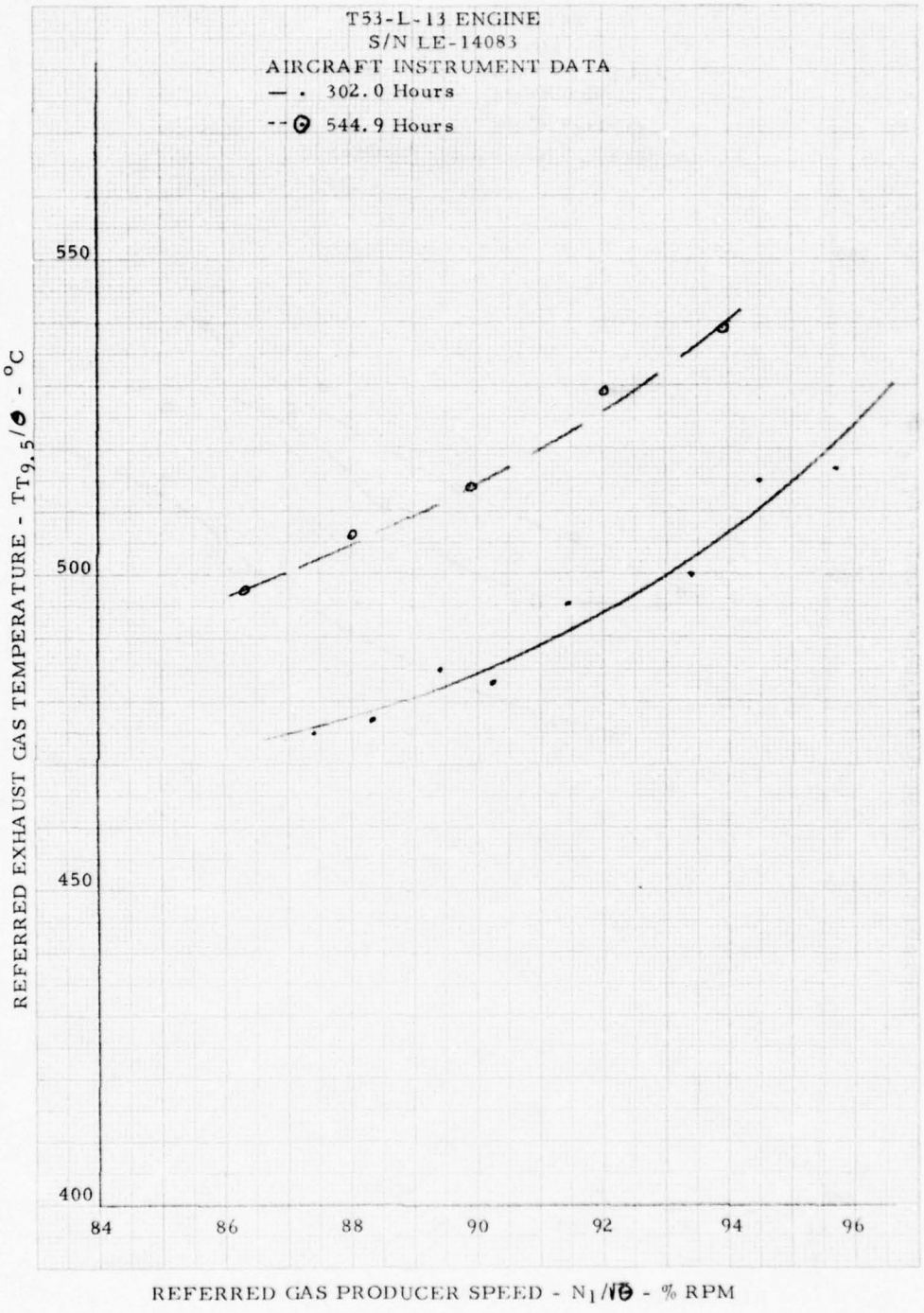
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— . 302.0 Hours
--⊙ 544.9 Hours
550
500
450
400
84
86
88
90
92
94
96
REFERRED EXHAUST GAS TEMPERATURE - $T_{T9.5}/\theta$ - °C
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 7.

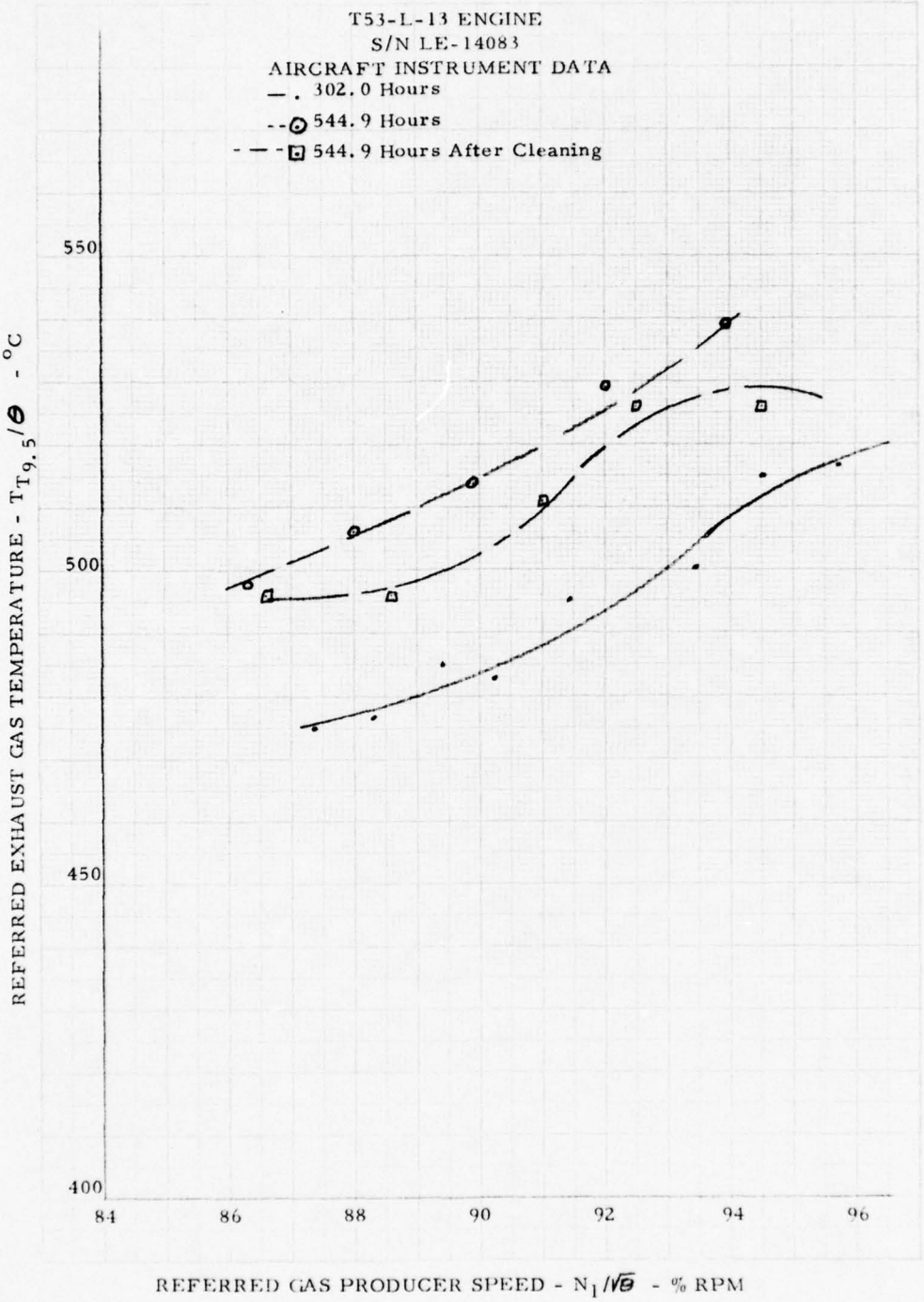
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
302.0 Hours
544.9 Hours
544.9 Hours After Cleaning
550
500
450
400
84
86
88
90
92
94
96
REFERRED EXHAUST GAS TEMPERATURE - $T_{T9.5}/\theta$ - °C
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 8.

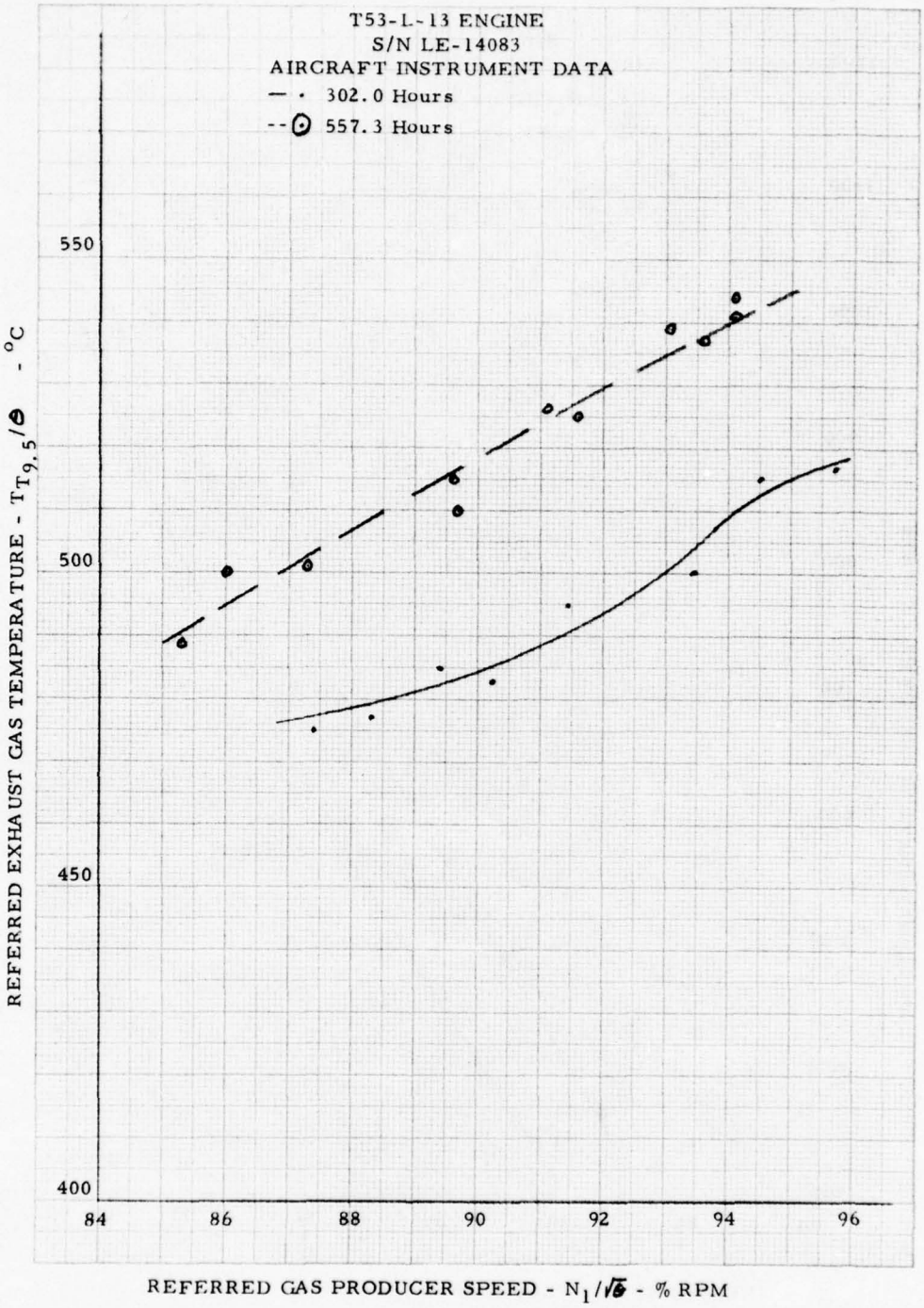
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— · 302.0 Hours
--⊙ 557.3 Hours
550
500
450
400
84
86
88
90
92
94
96
REFERRED EXHAUST GAS TEMPERATURE - $T_{T9.5}/\theta$ - °C
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 9.

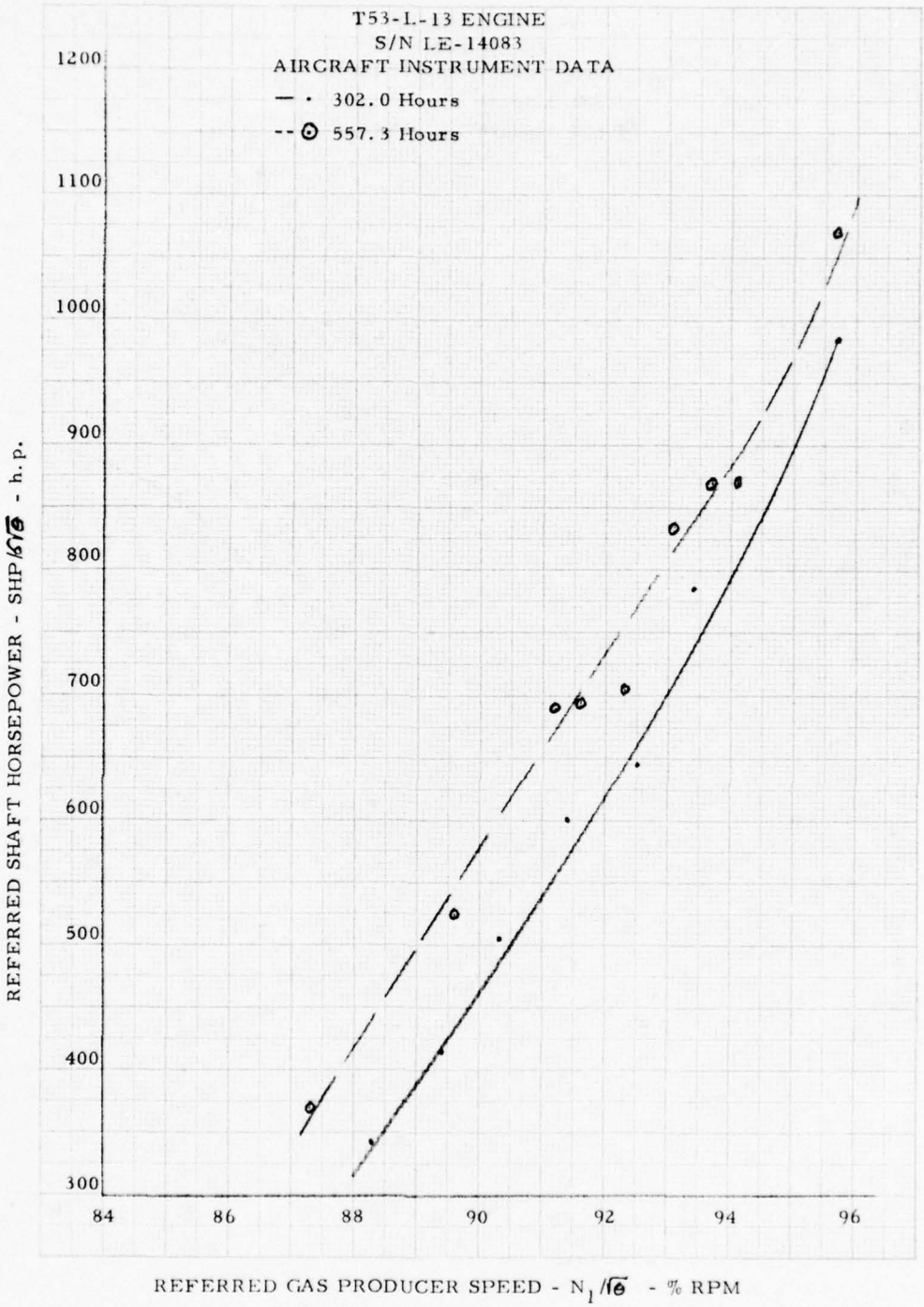
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
302.0 Hours
557.3 Hours
REFERRED SHAFT HORSEPOWER - SHP/δθ - h.p.
1200
1100
1000
900
800
700
600
500
400
300
84
86
88
90
92
94
96
REFERRED GAS PRODUCER SPEED - N1/√θ - % RPM

Figure 10.

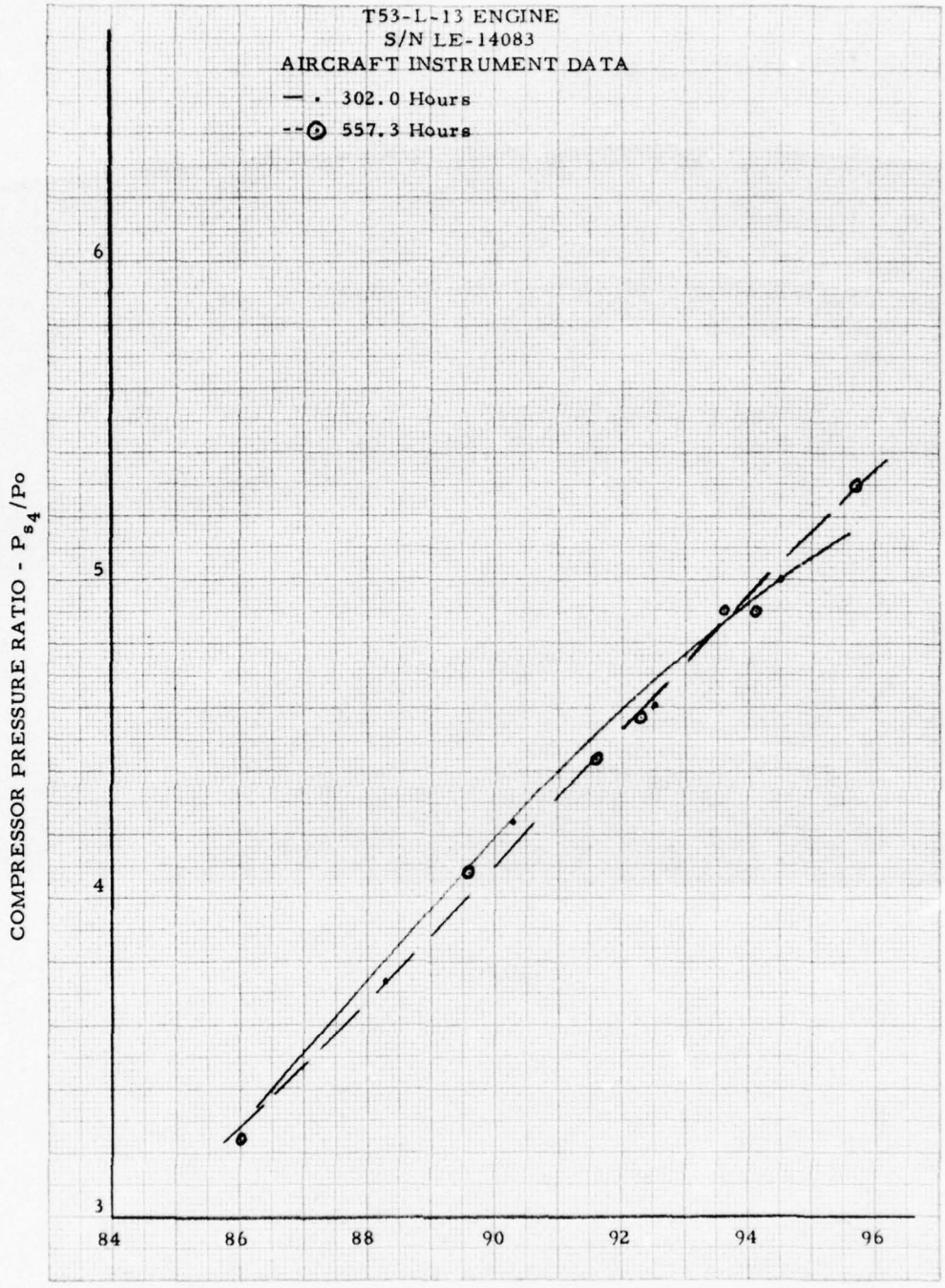
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
302.0 Hours
557.3 Hours
COMPRESSOR PRESSURE RATIO - P_{s_4}/Po
6
5
4
3
84
86
88
90
92
94
96
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 11.

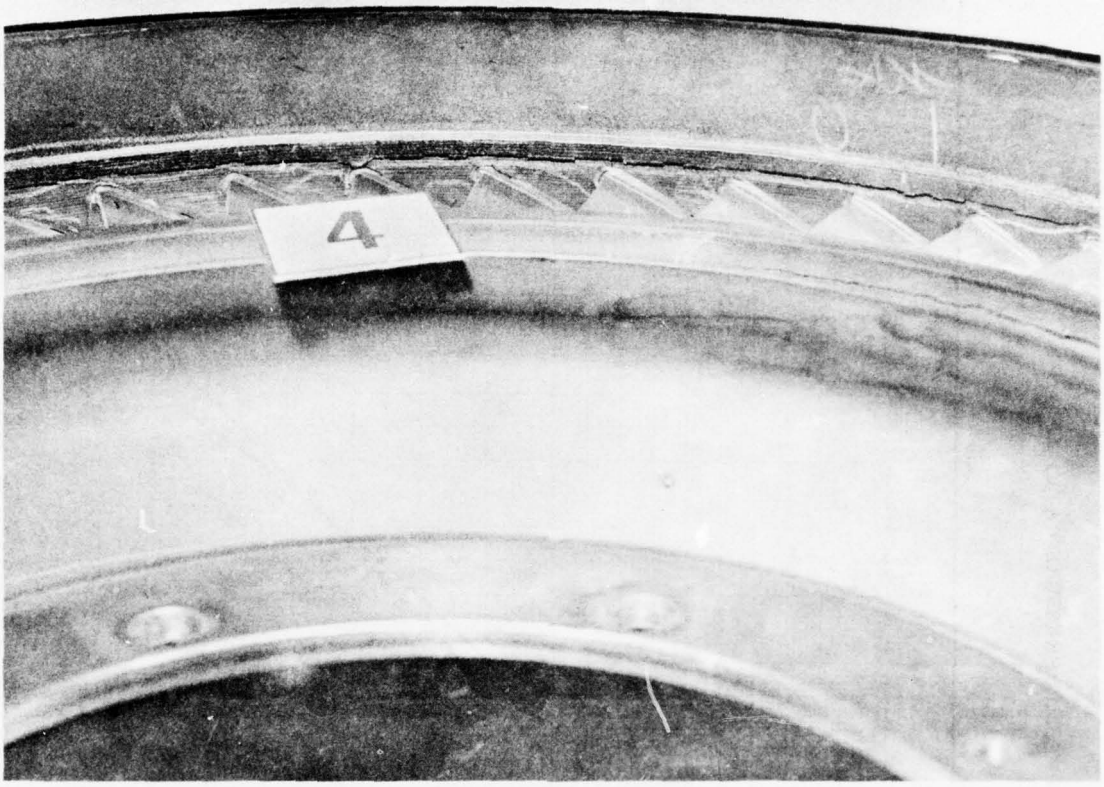

Figure 12.

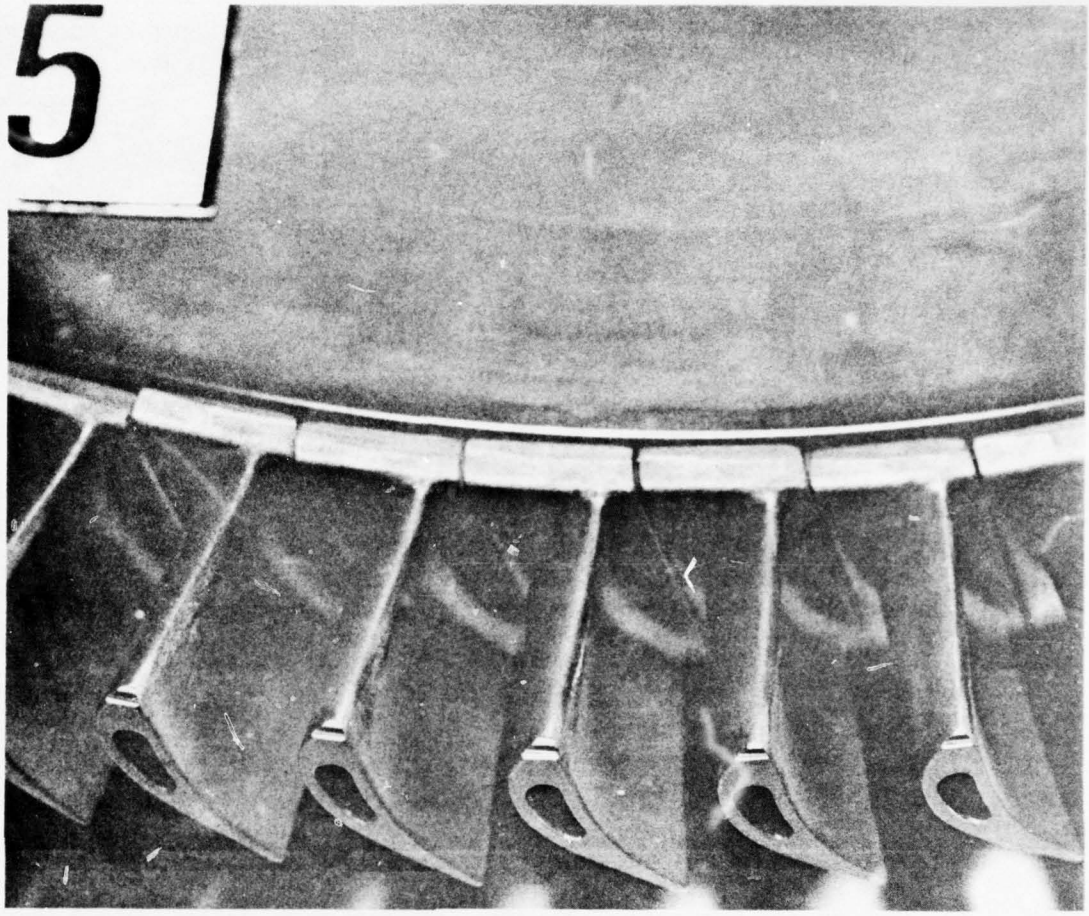

Figure 13.

Figure 14.

Figure 15.

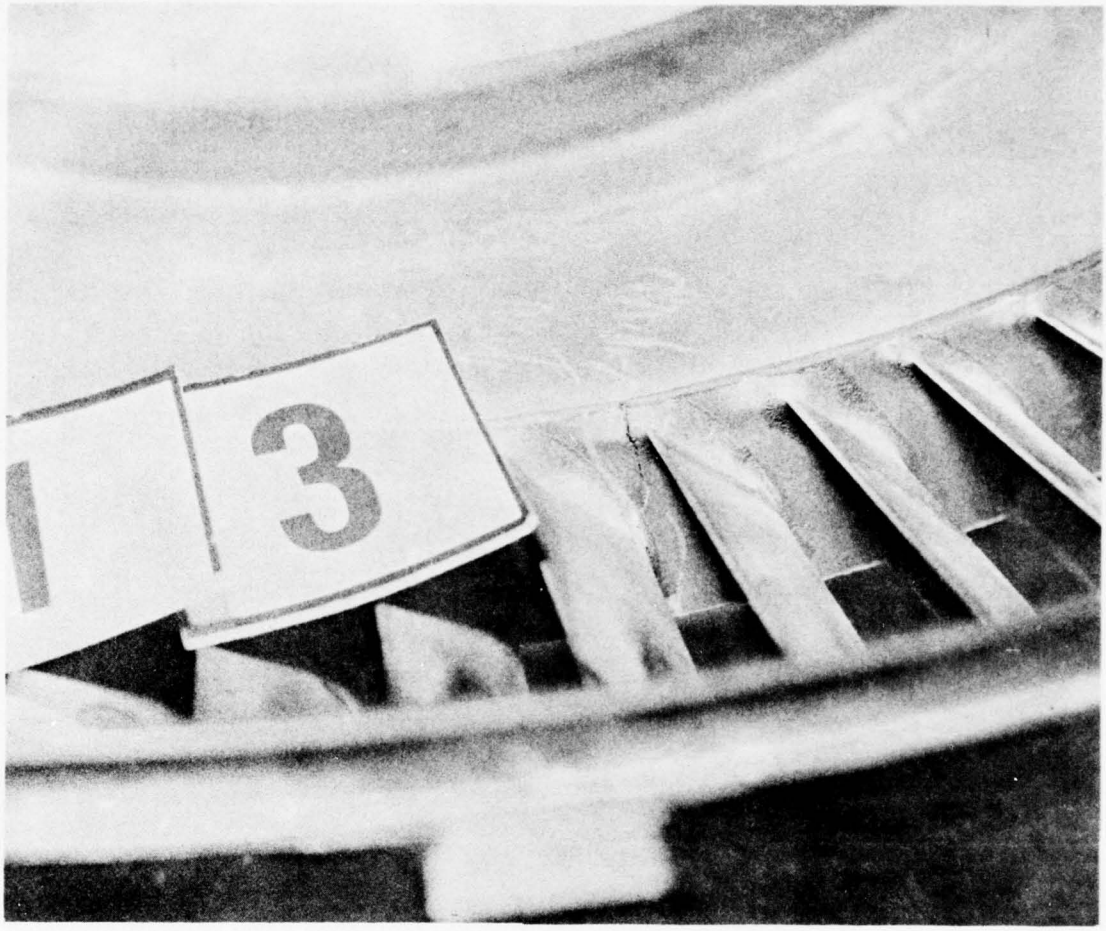

Figure 16.

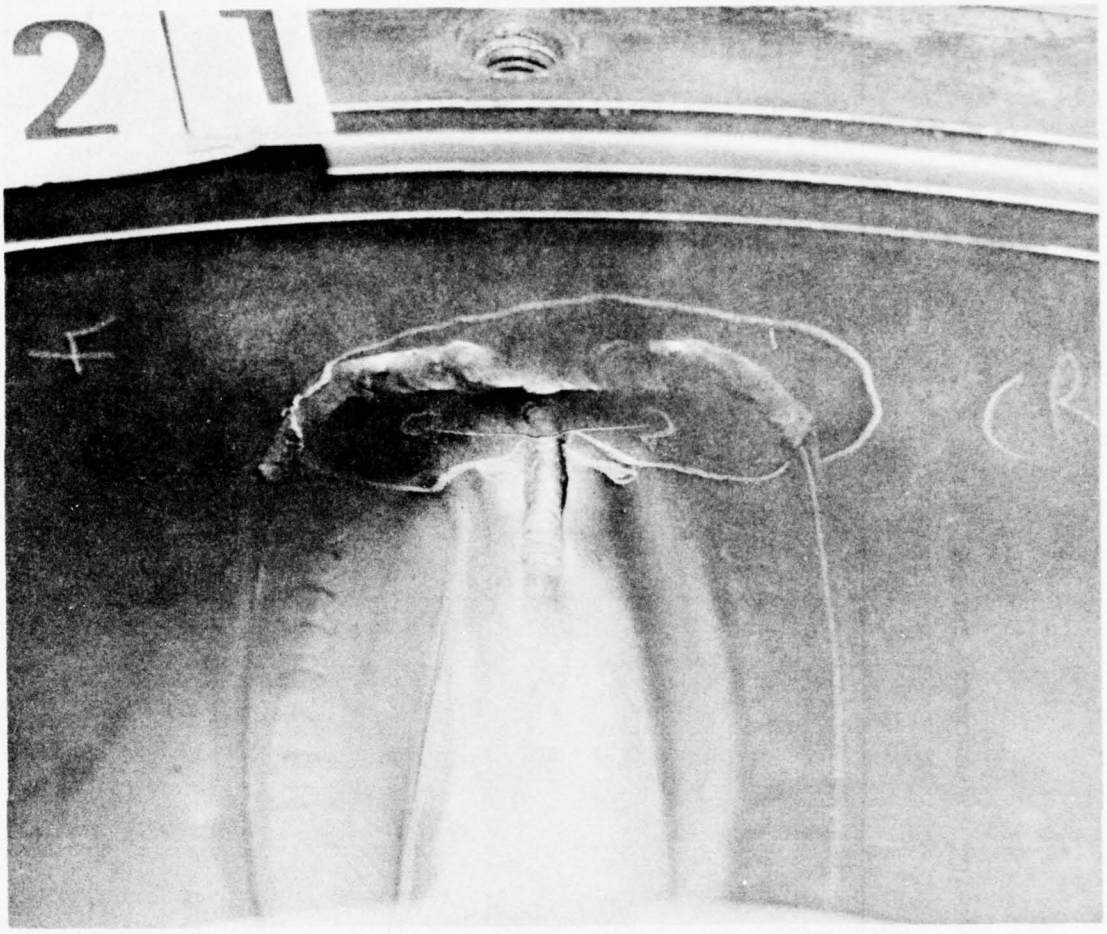

Figure 17.

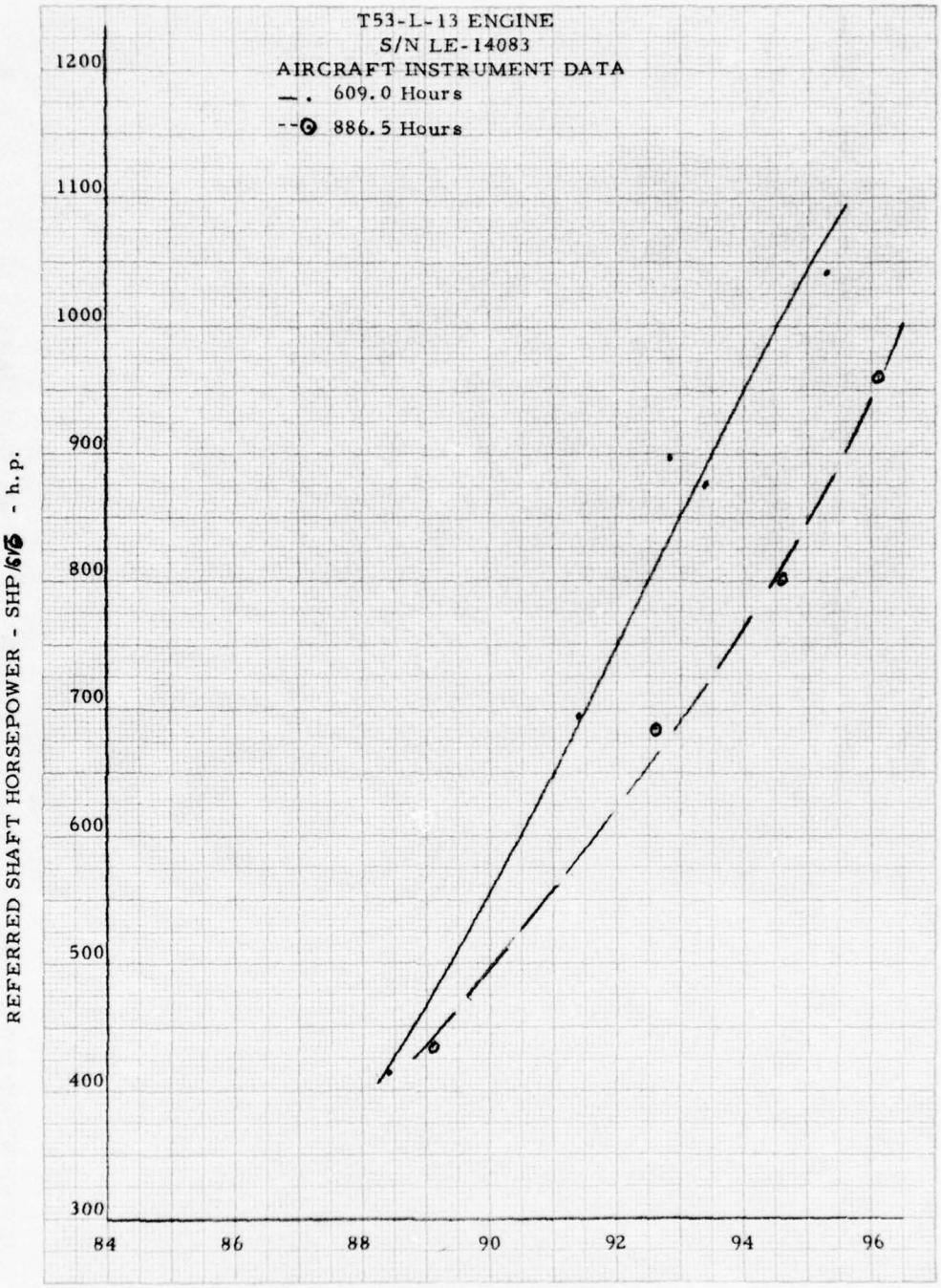
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
609.0 Hours
886.5 Hours
1200
1100
1000
900
800
700
600
500
400
300
84
86
88
90
92
94
96
REFERRED SHAFT HORSEPOWER - SHP/√θ - h.p.
REFERRED GAS PRODUCER SPEED - N1/√θ - % RPM

Figure 18.

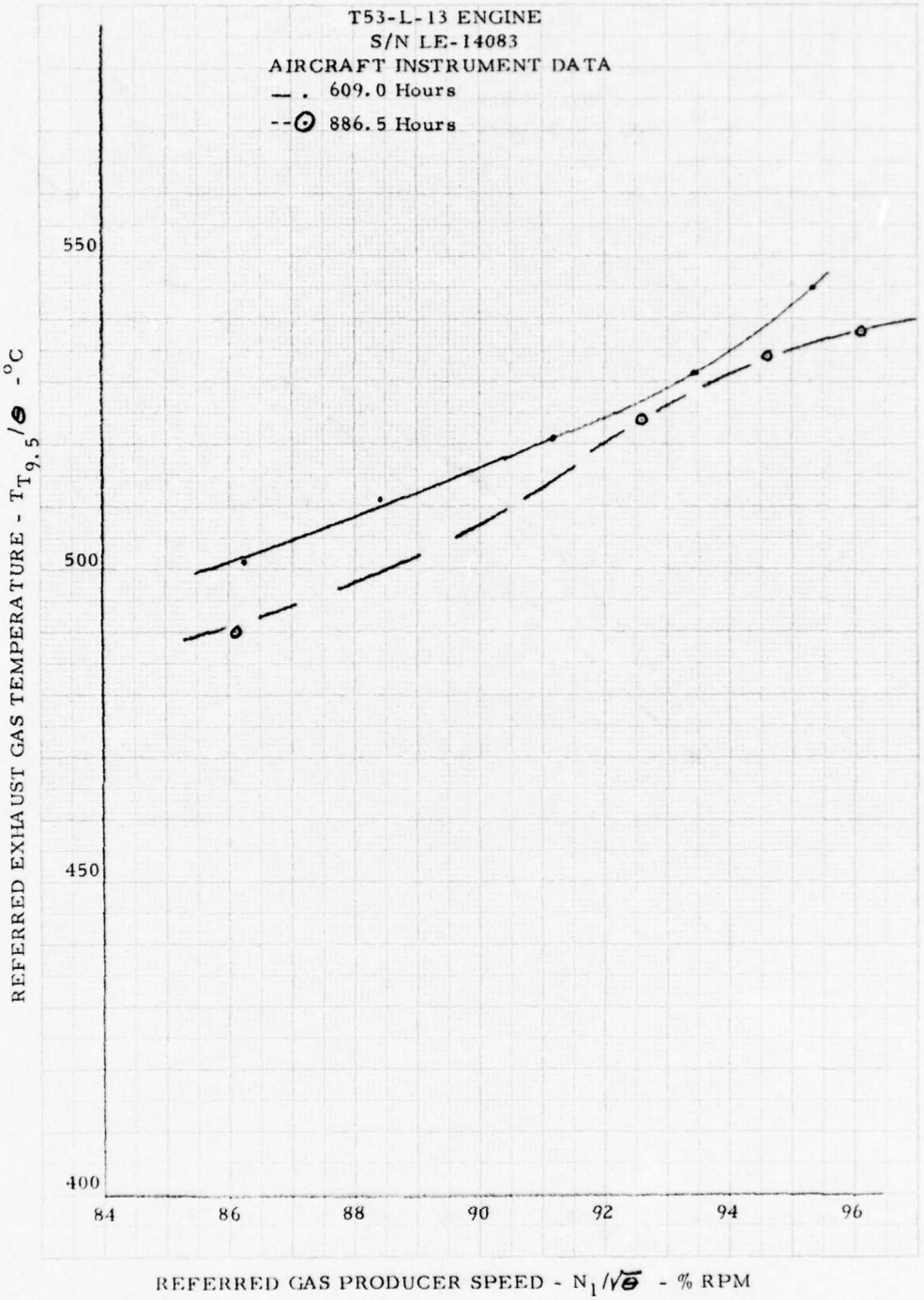
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
609.0 Hours
886.5 Hours
550
500
450
400
84
86
88
90
92
94
96
REFERRED EXHAUST GAS TEMPERATURE - $T_{T9.5}/\theta$ - °C
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 19.

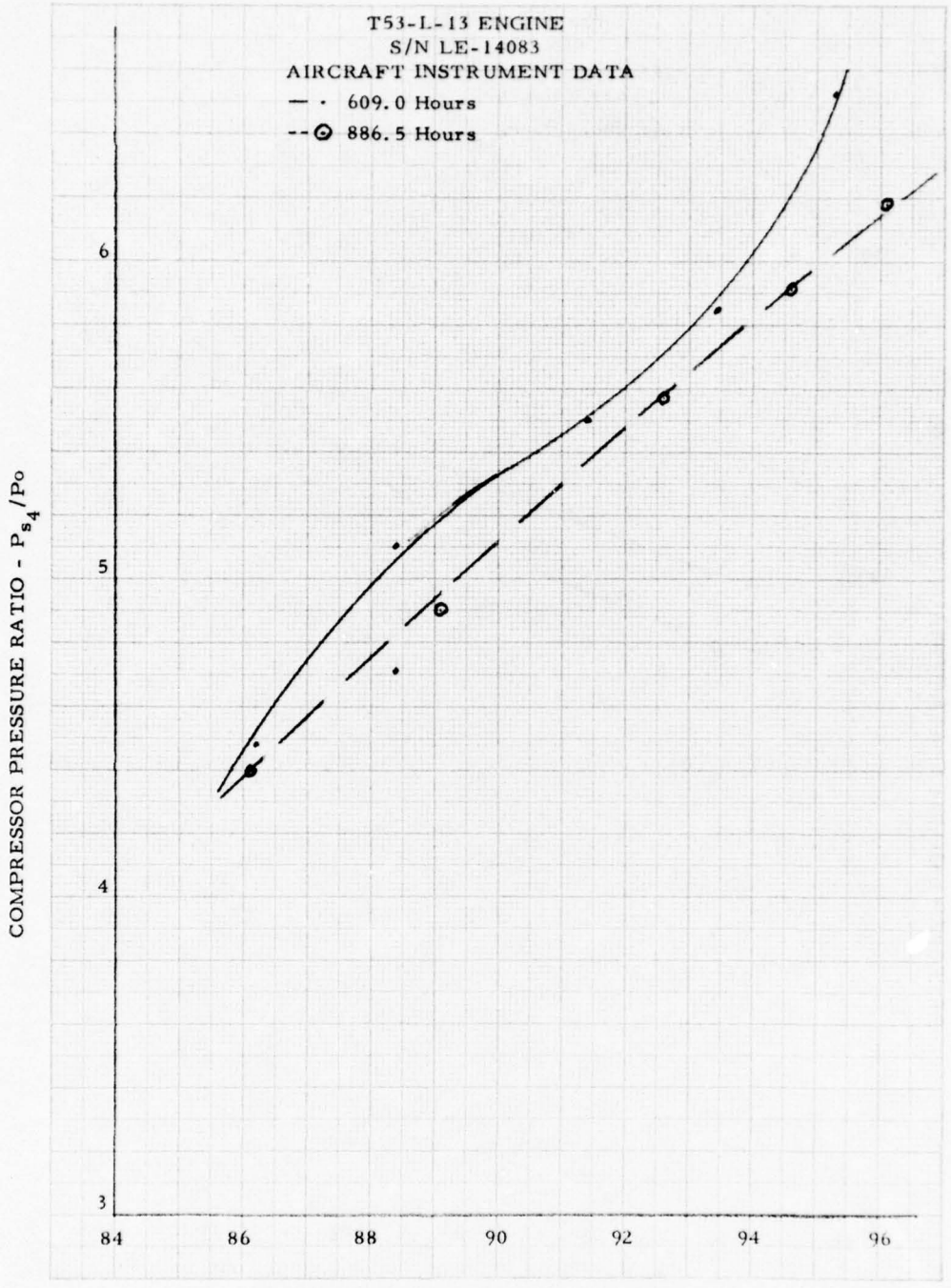
T53-L-13 ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
609.0 Hours
886.5 Hours
COMPRESSOR PRESSURE RATIO - P_{s_4}/P_o
6
5
4
3
84
86
88
90
92
94
96
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 20.

Figure 21.

Figure 22.

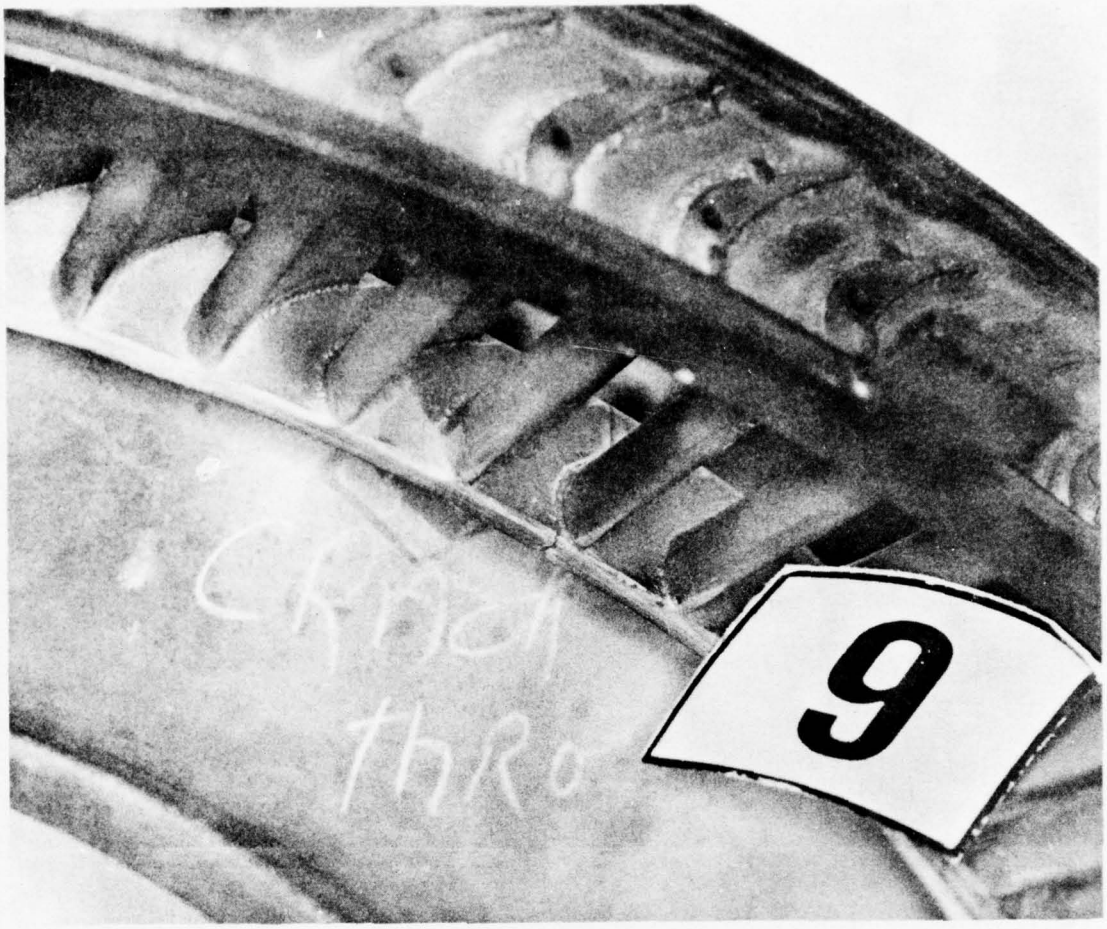

Figure 23.

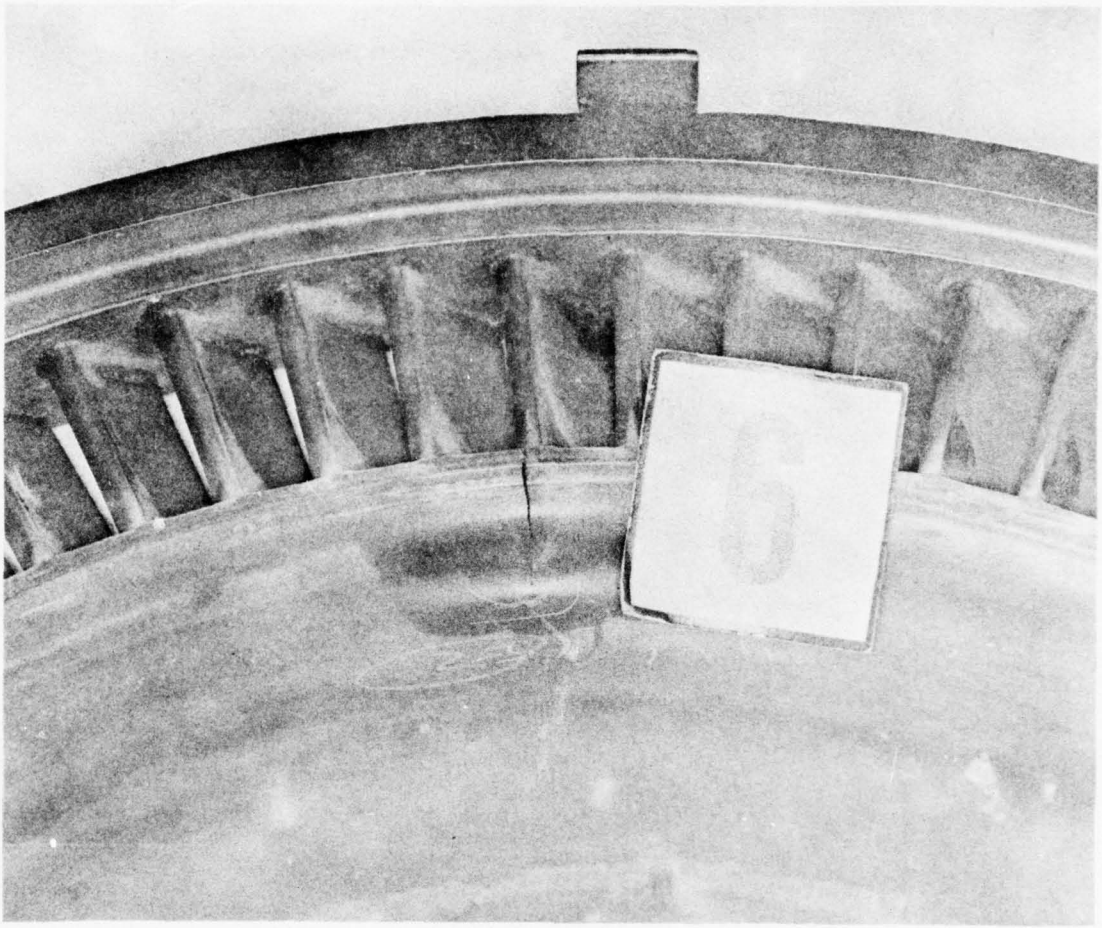

Figure 24.

Figure 25.

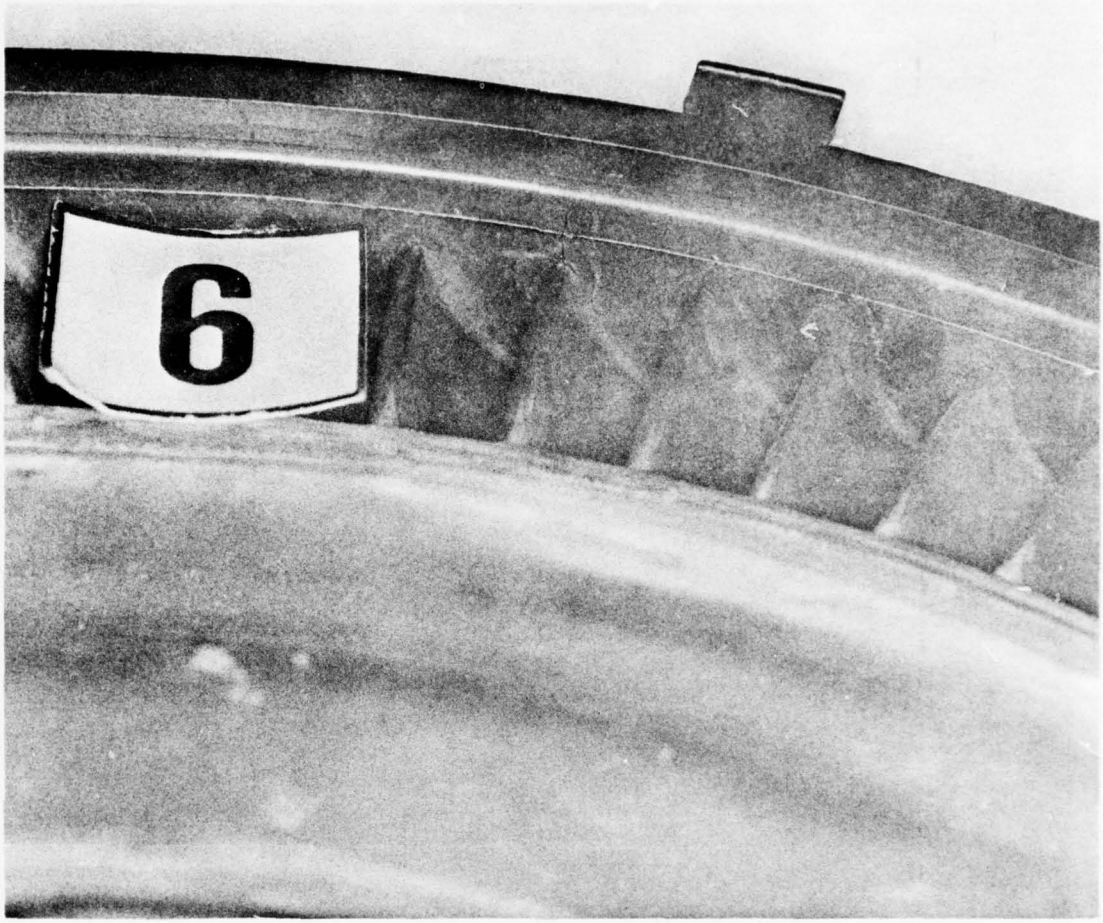

Figure 26.

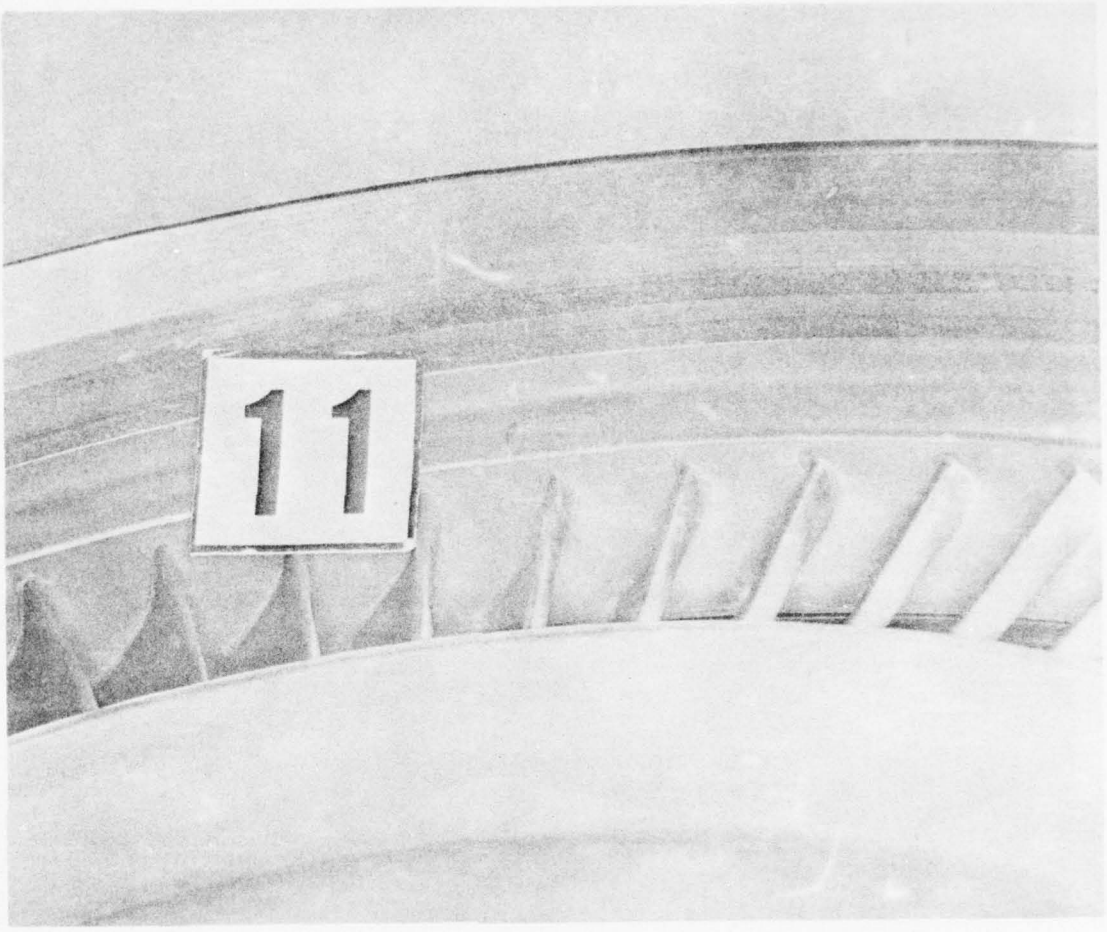

Figure 27.

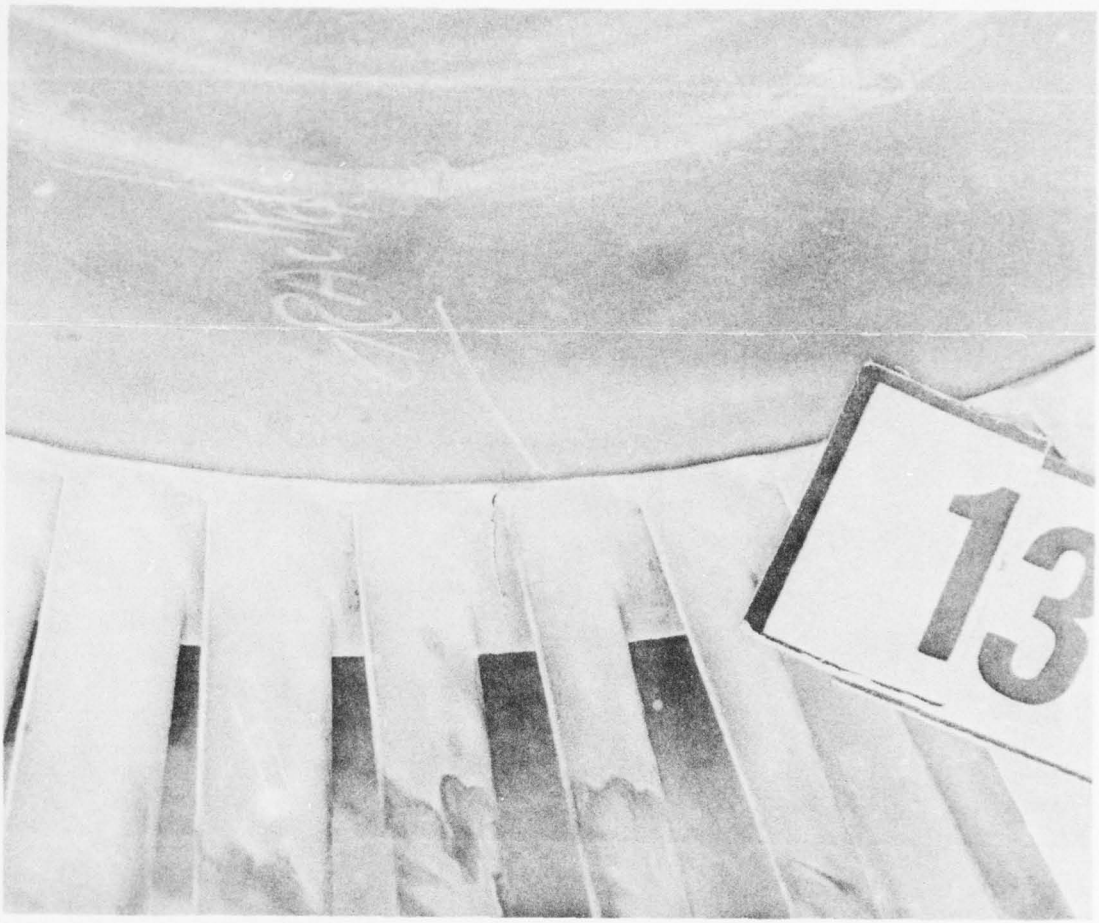

Figure 28.

Figure 29.

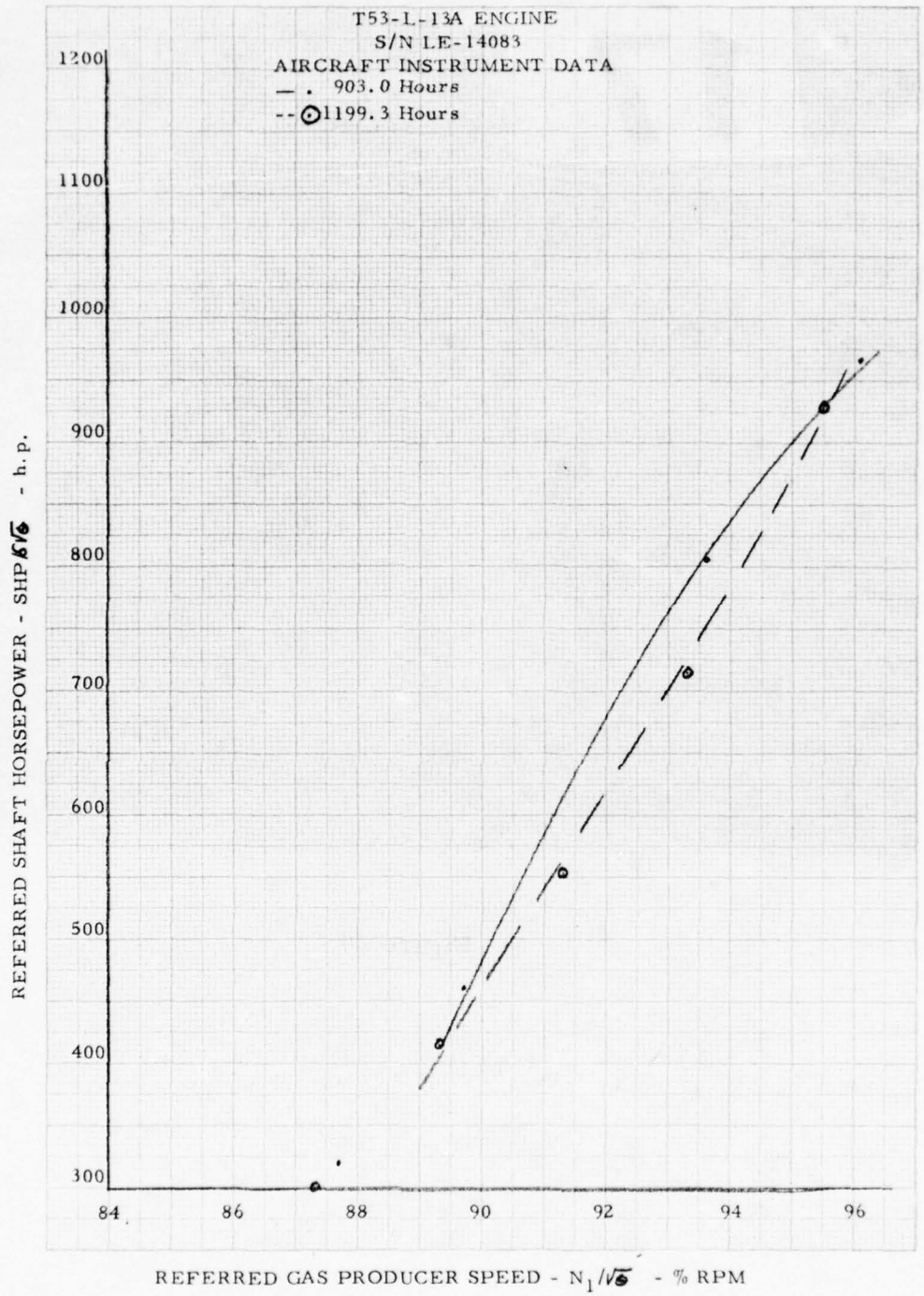
T53-L-13A ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— . 903.0 Hours
-- ⊙ 1199.3 Hours
1200
1100
1000
900
800
700
600
500
400
300
84
86
88
90
92
94
96
REFERRED SHAFT HORSEPOWER - SHP/δ√θ - h.p.
REFERRED GAS PRODUCER SPEED - N1/√θ - % RPM

Figure 30.

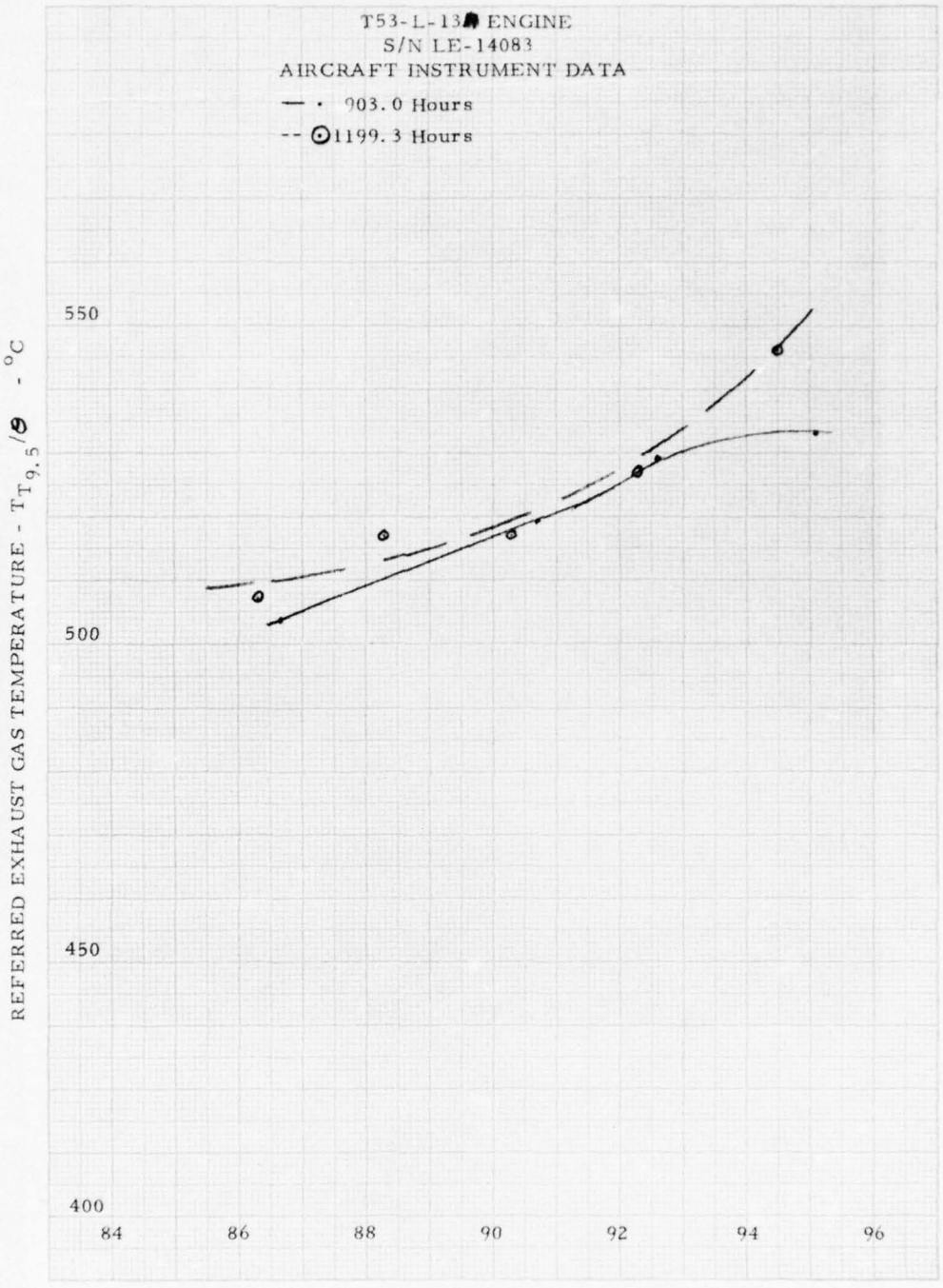
T53-L-13A ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— · 903.0 Hours
-- ⊙1199.3 Hours
550
500
450
400
84
86
88
90
92
94
96
REFERRED EXHAUST GAS TEMPERATURE - $T_{T9.5}/\theta$ - °C
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 31.

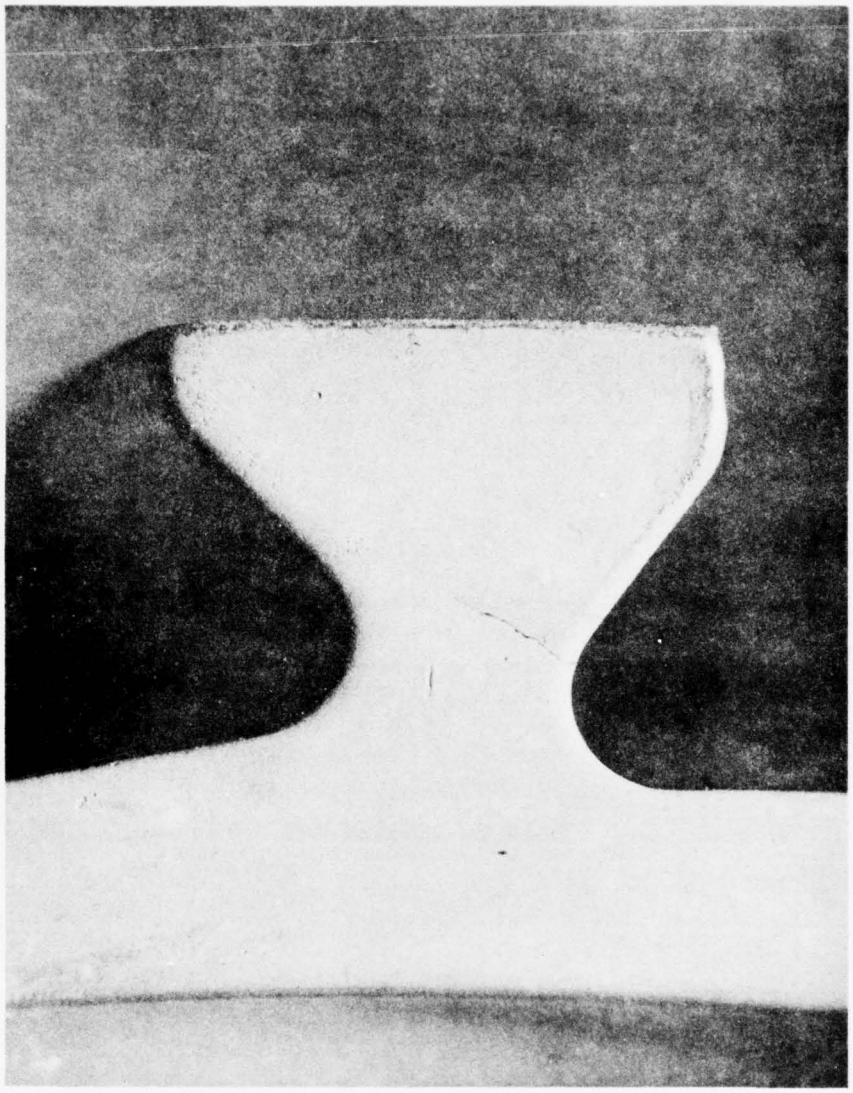

Figure 32.

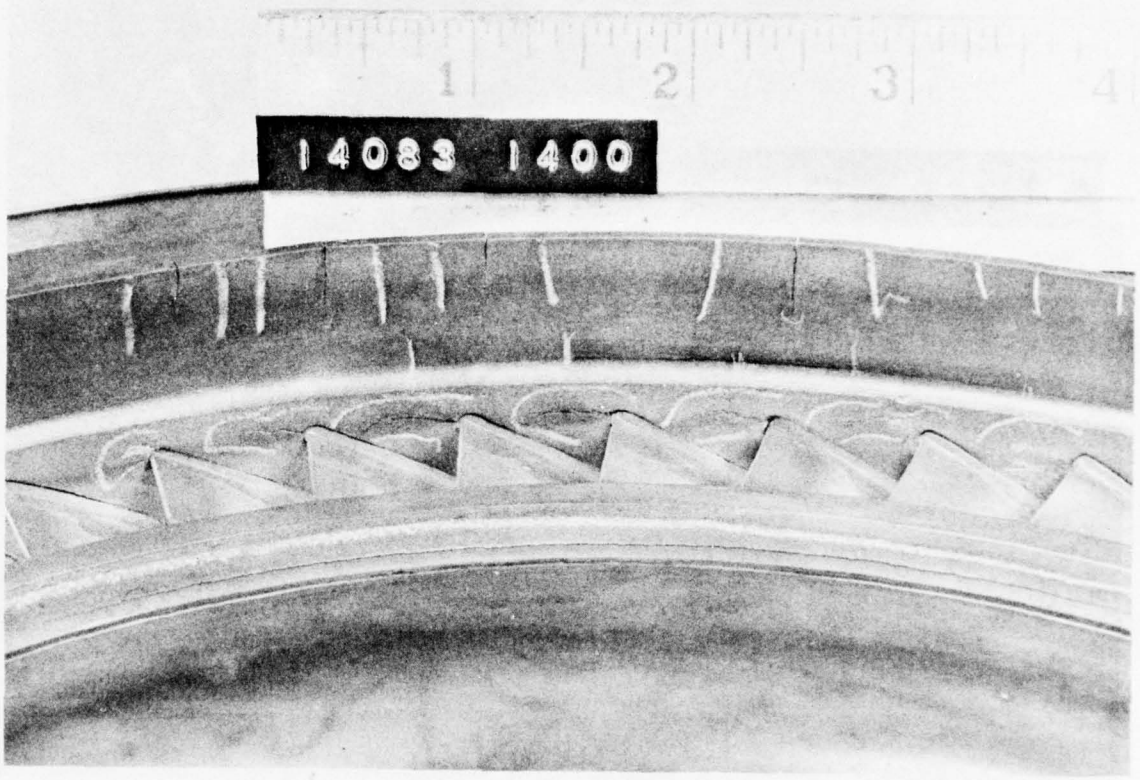

Figure 33.

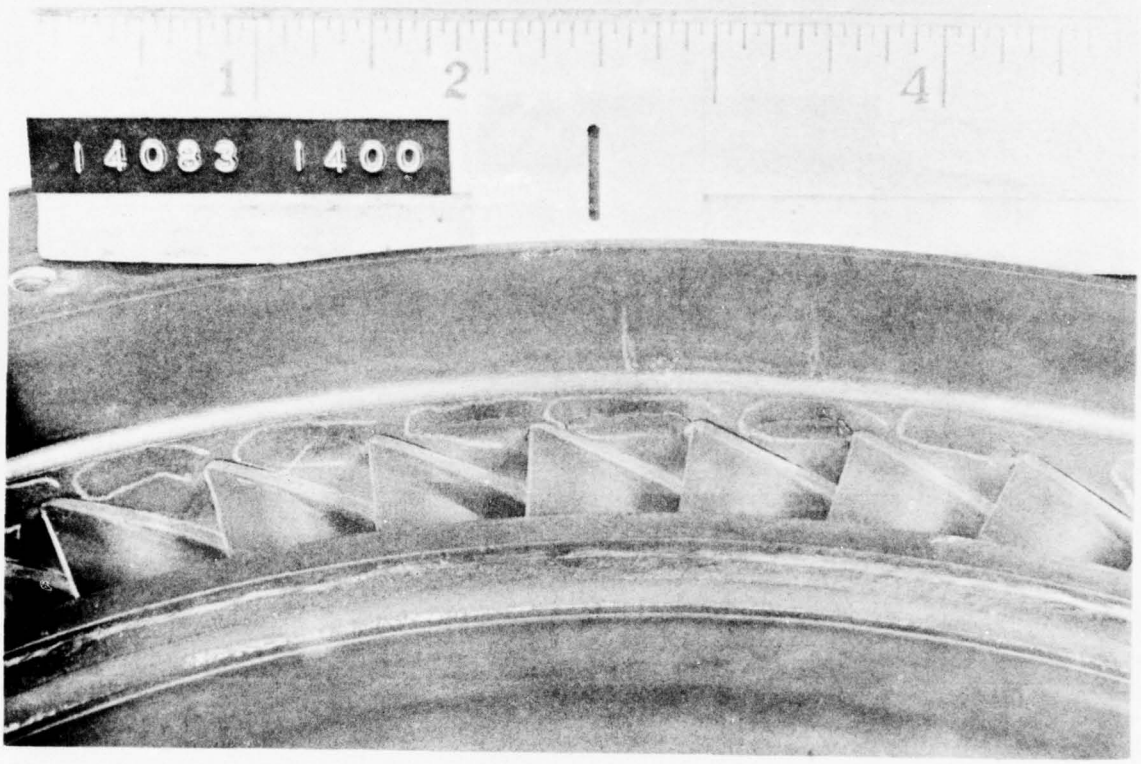

Figure 34.

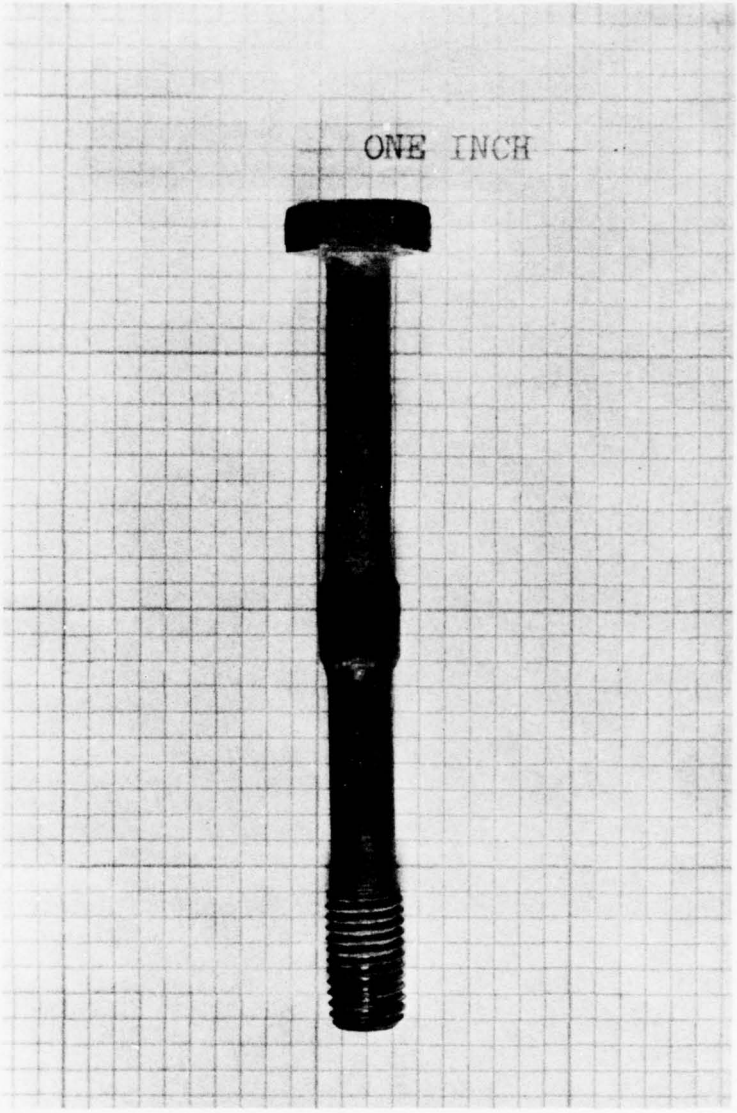

Figure 35.

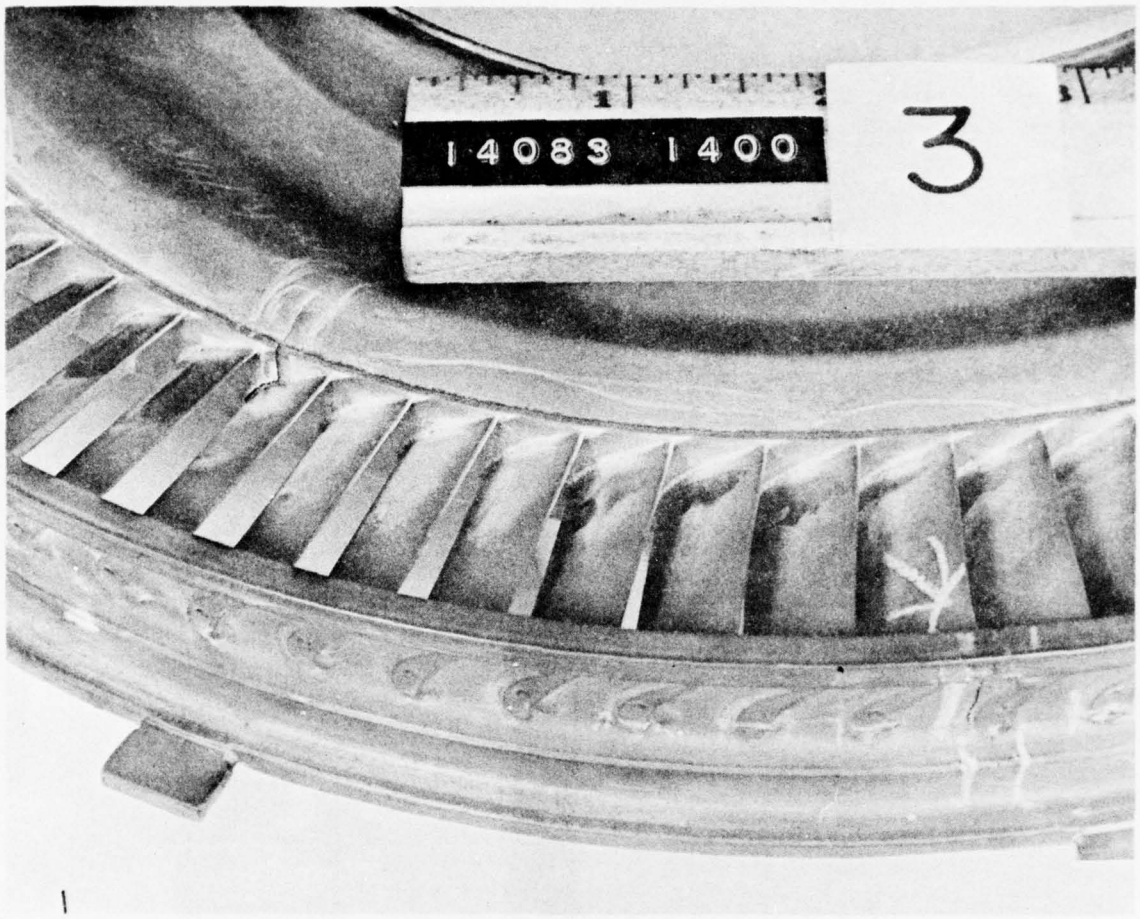

Figure 36.

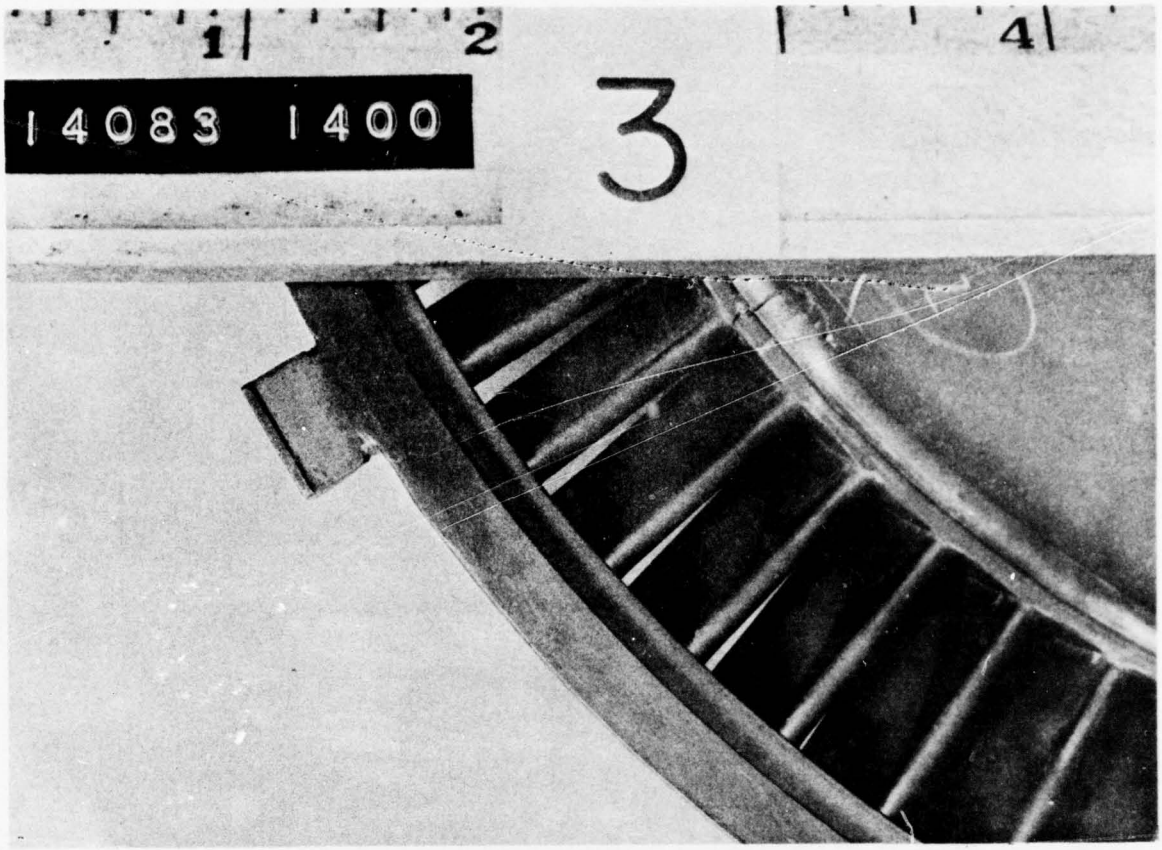

Figure 37.

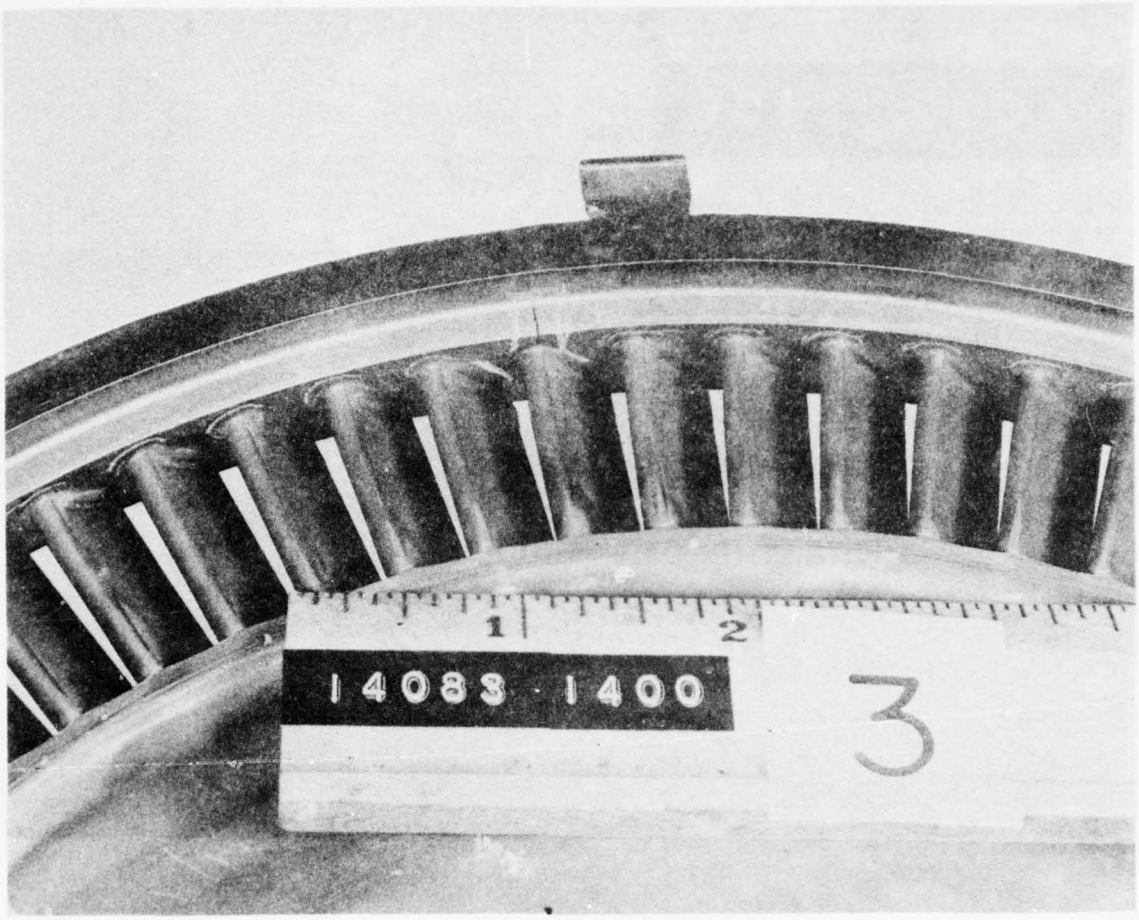

Figure 38.

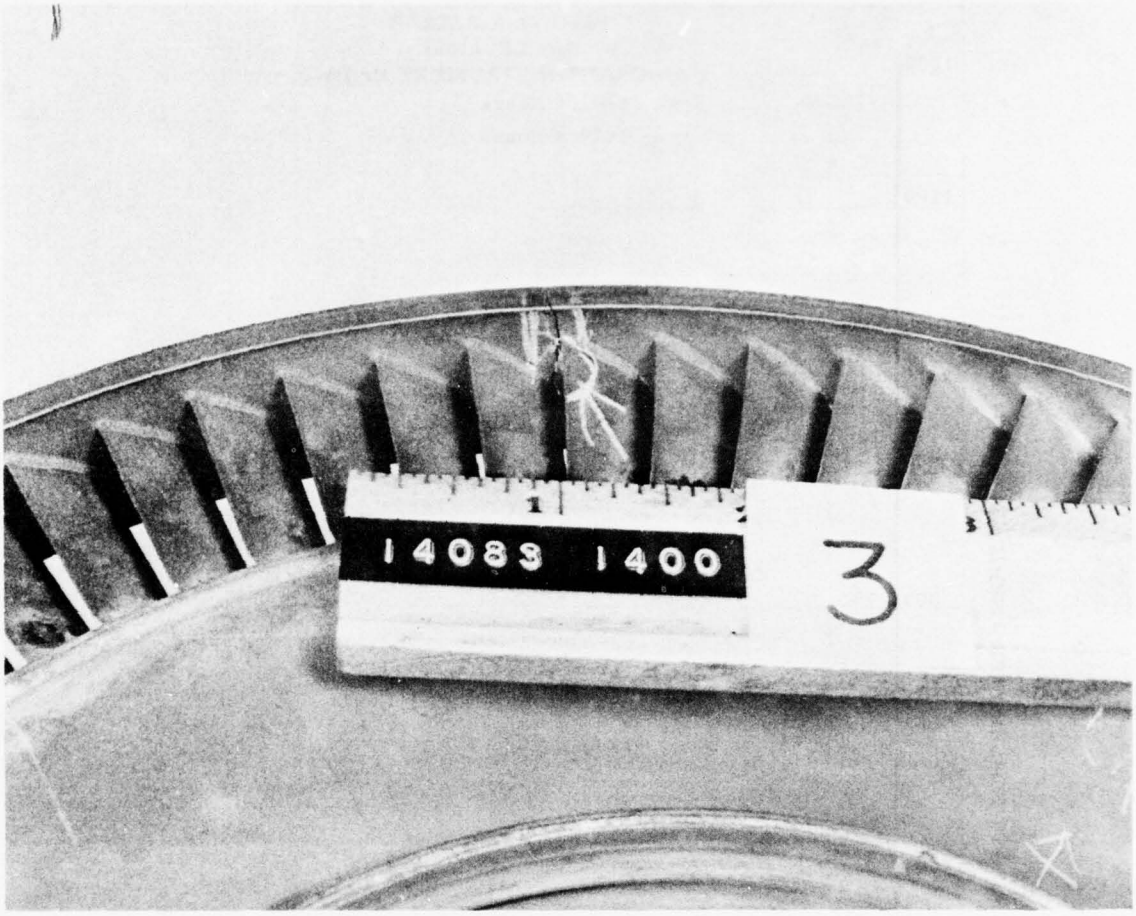

Figure 39.

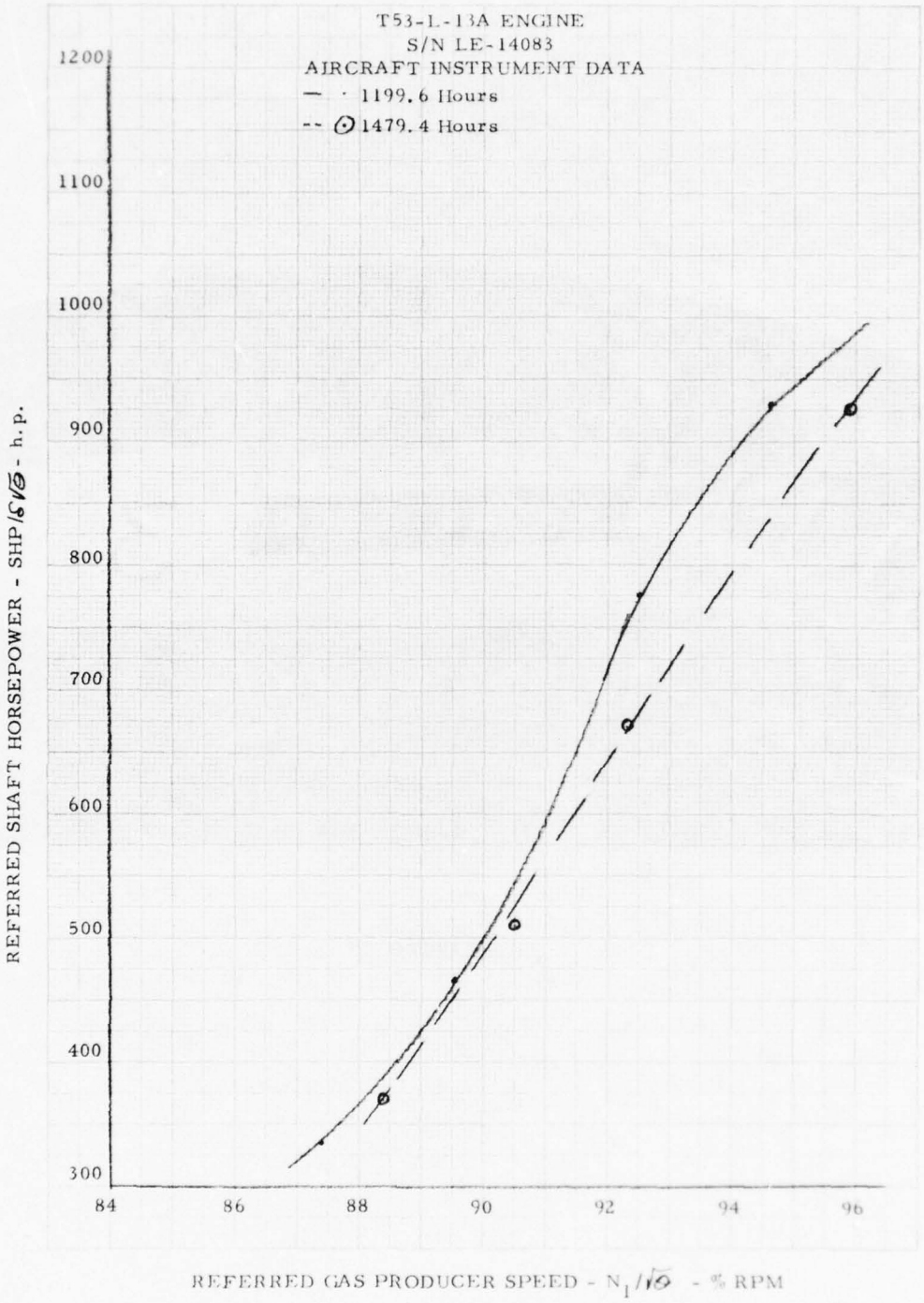
T53-L-13A ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— · 1199.6 Hours
-- ⊙ 1479.4 Hours
1200
1100
1000
900
800
700
600
500
400
300
84
86
88
90
92
94
96
REFERRED SHAFT HORSEPOWER - SHP/δ√θ - h.p.
REFERRED GAS PRODUCER SPEED - N1/√θ - % RPM

Figure 40.

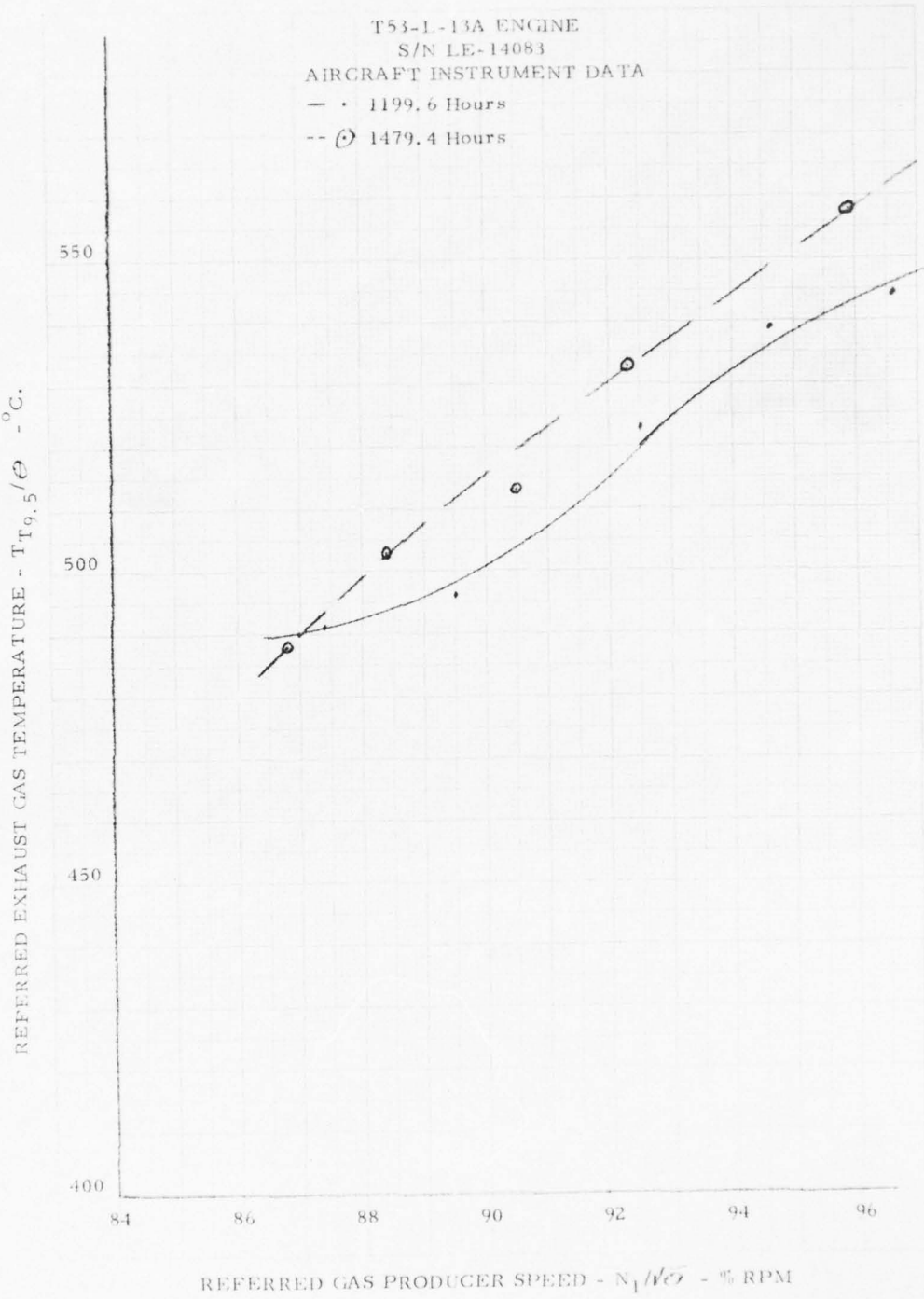
T53-L-13A ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— · 1199.6 Hours
-- ⊙ 1479.4 Hours
550
500
450
400
84
86
88
90
92
94
96
REFERRED EXHAUST GAS TEMPERATURE - $T_{T9.5}/\theta$ - °C.
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 41.

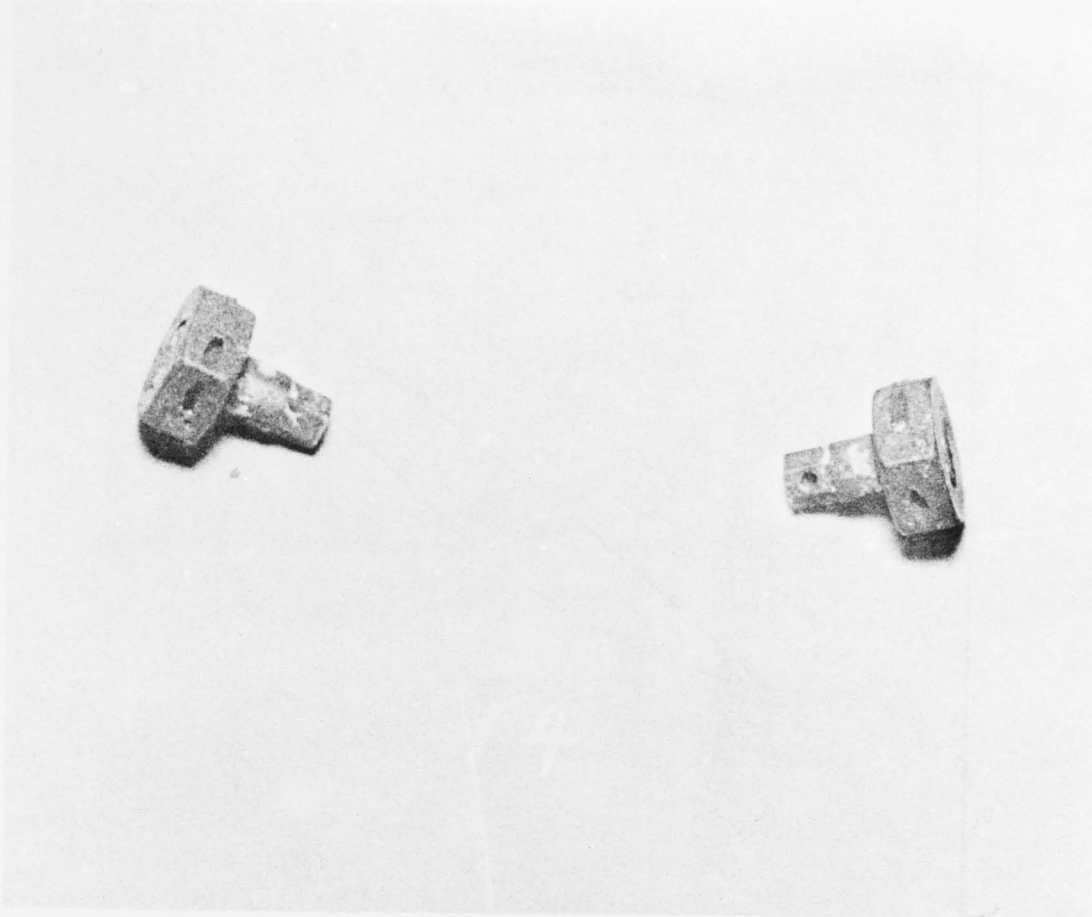

Figure 42.

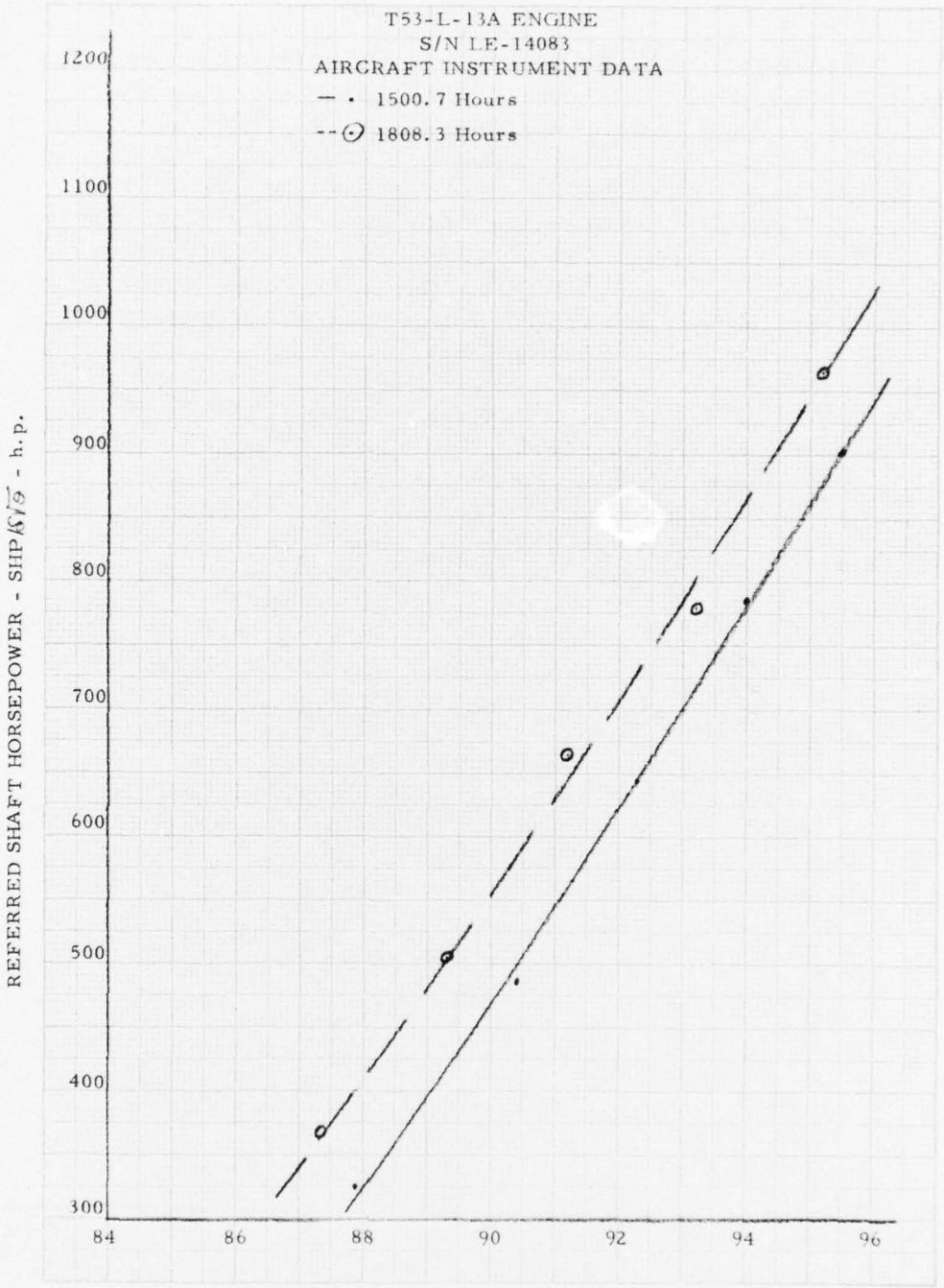
T53-L-13A ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— · 1500.7 Hours
--⊙ 1808.3 Hours
1200
1100
1000
900
800
700
600
500
400
300
84
86
88
90
92
94
96
REFERRED SHAFT HORSEPOWER - SHP/$\sqrt{\theta}$ - h.p.
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 43.

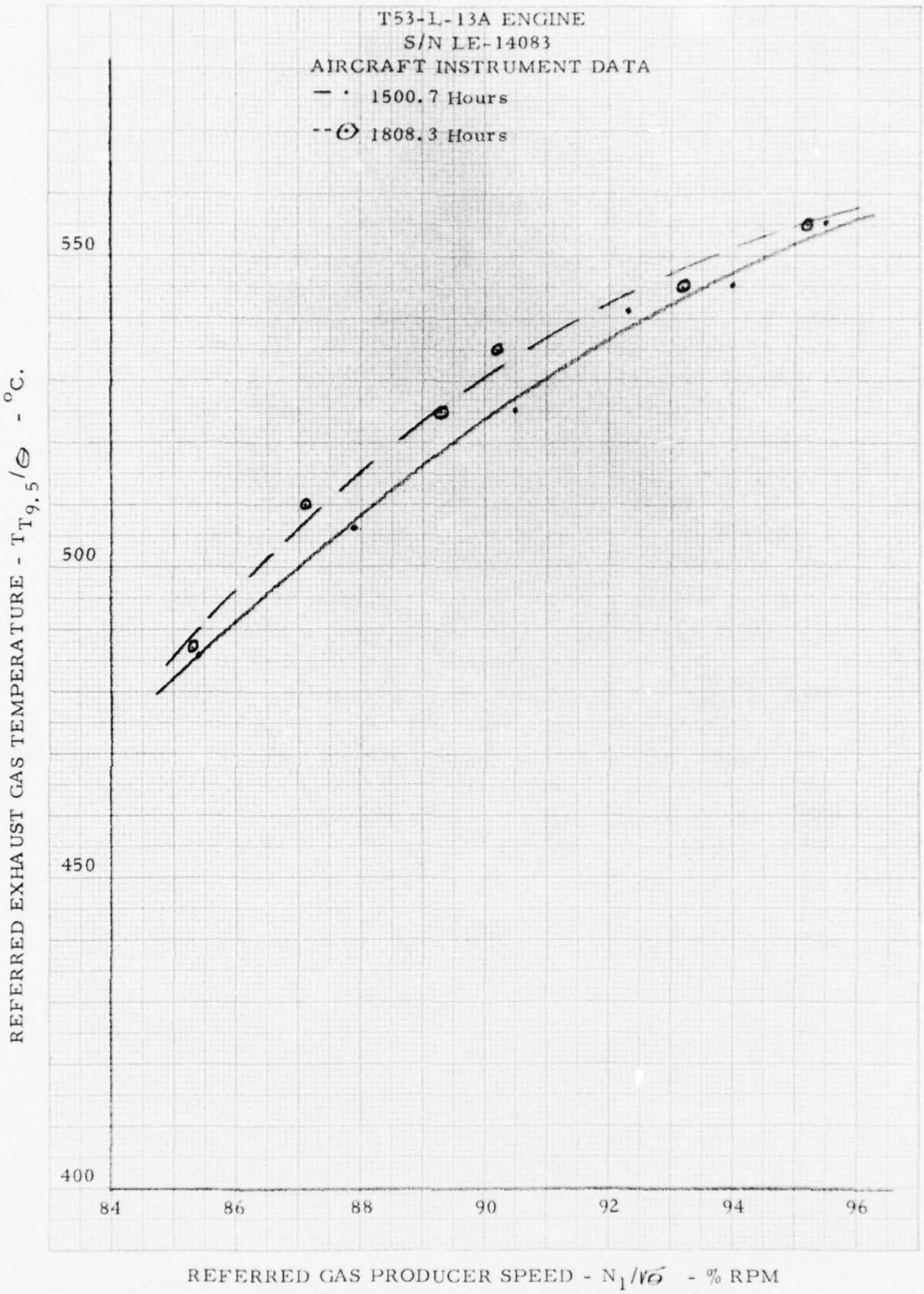
T53-L-13A ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
1500.7 Hours
1808.3 Hours
550
500
450
400
84
86
88
90
92
94
96
REFERRED EXHAUST GAS TEMPERATURE - $T_{T9.5}/\theta$ - °C.
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 44.

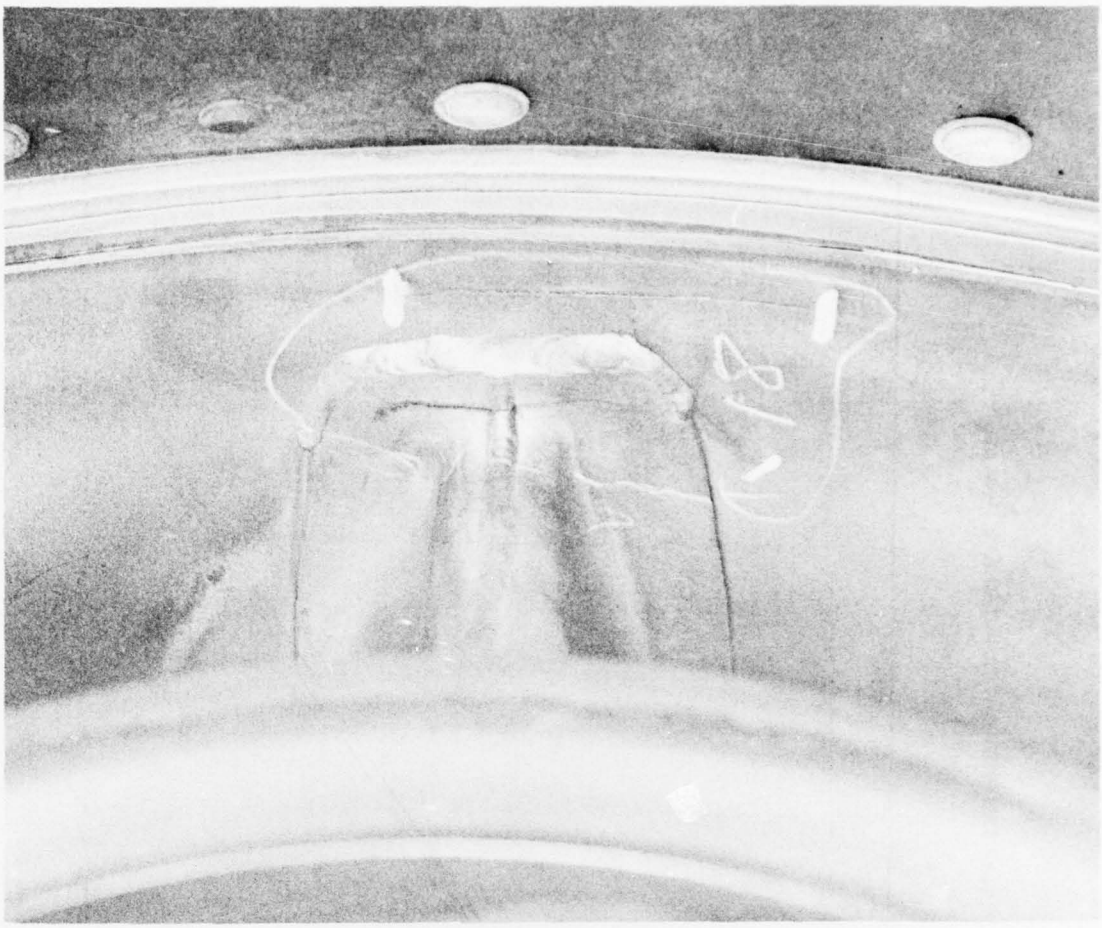

Figure 45.

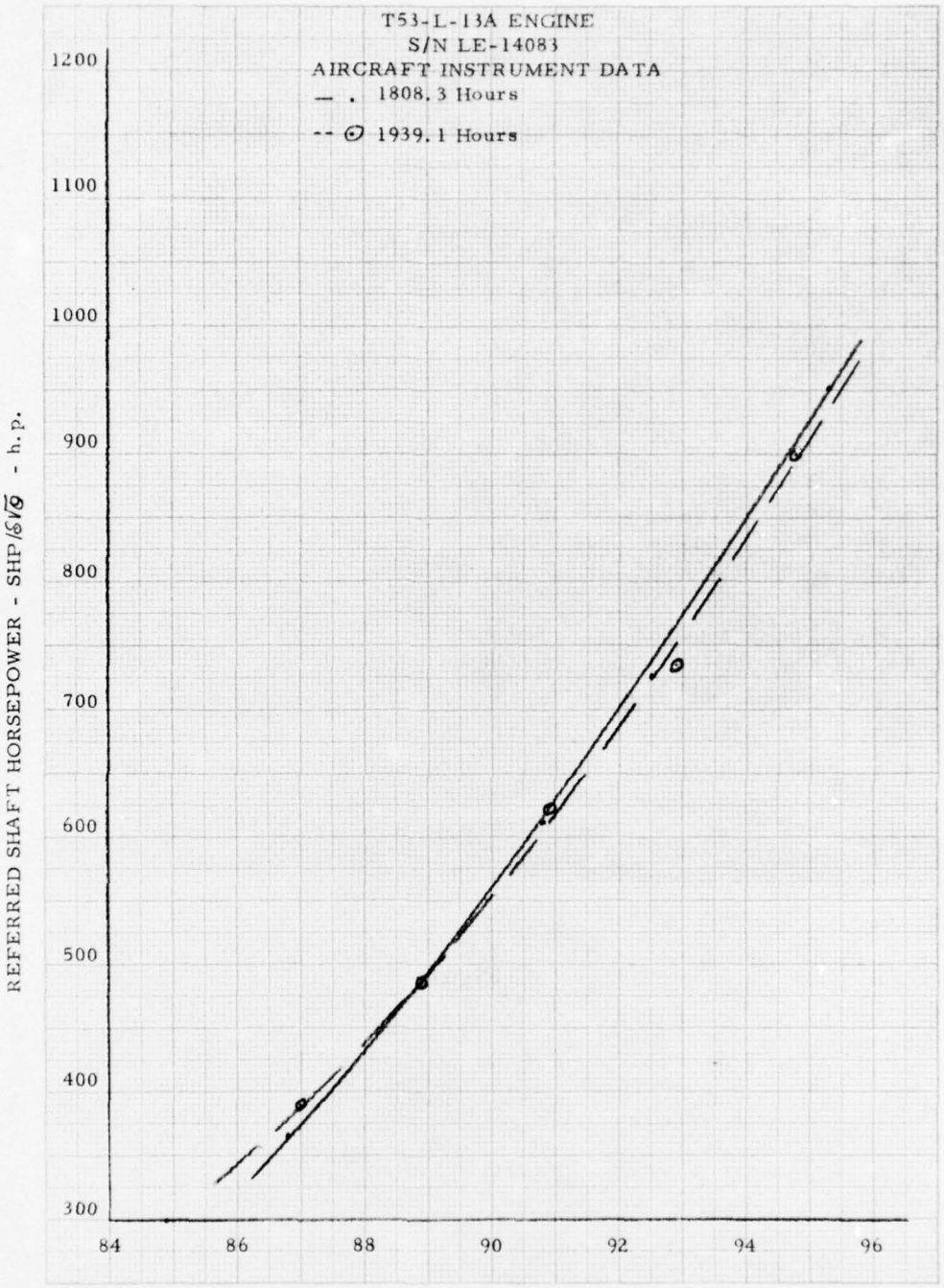
T53-L-13A ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— . 1808.3 Hours
-- ⊙ 1939.1 Hours
1200
1100
1000
900
800
700
600
500
400
300
84
86
88
90
92
94
96
REFERRED SHAFT HORSEPOWER - SHP/δ√θ - h.p.
REFERRED GAS PRODUCER SPEED - N1/√θ - % RPM

Figure 46.

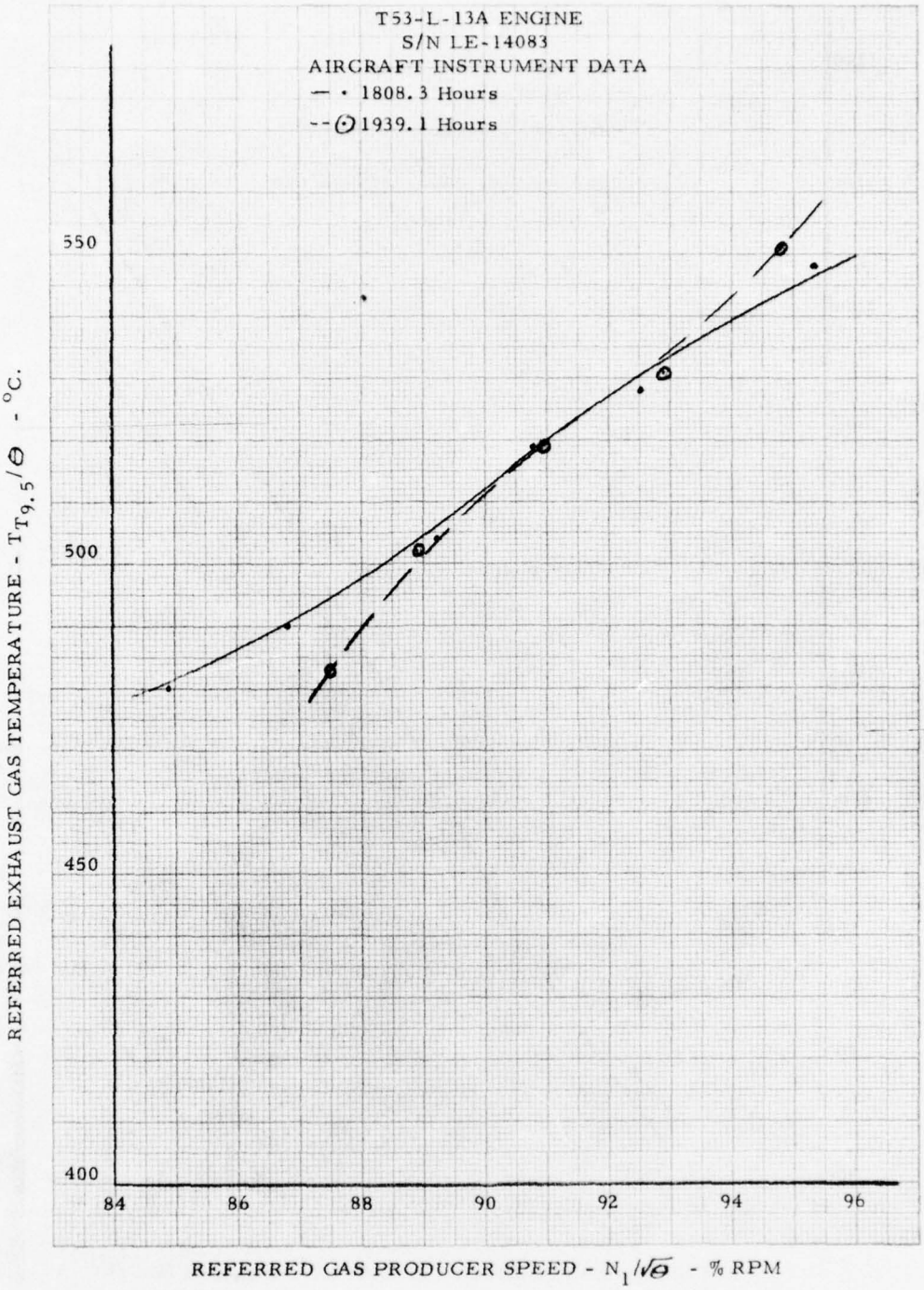
T53-L-13A ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— · 1808.3 Hours
--⊙ 1939.1 Hours
550
500
450
400
84
86
88
90
92
94
96
REFERRED EXHAUST GAS TEMPERATURE - $T_{T9.5}/\theta$ - °C.
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\theta}$ - % RPM

Figure 47.

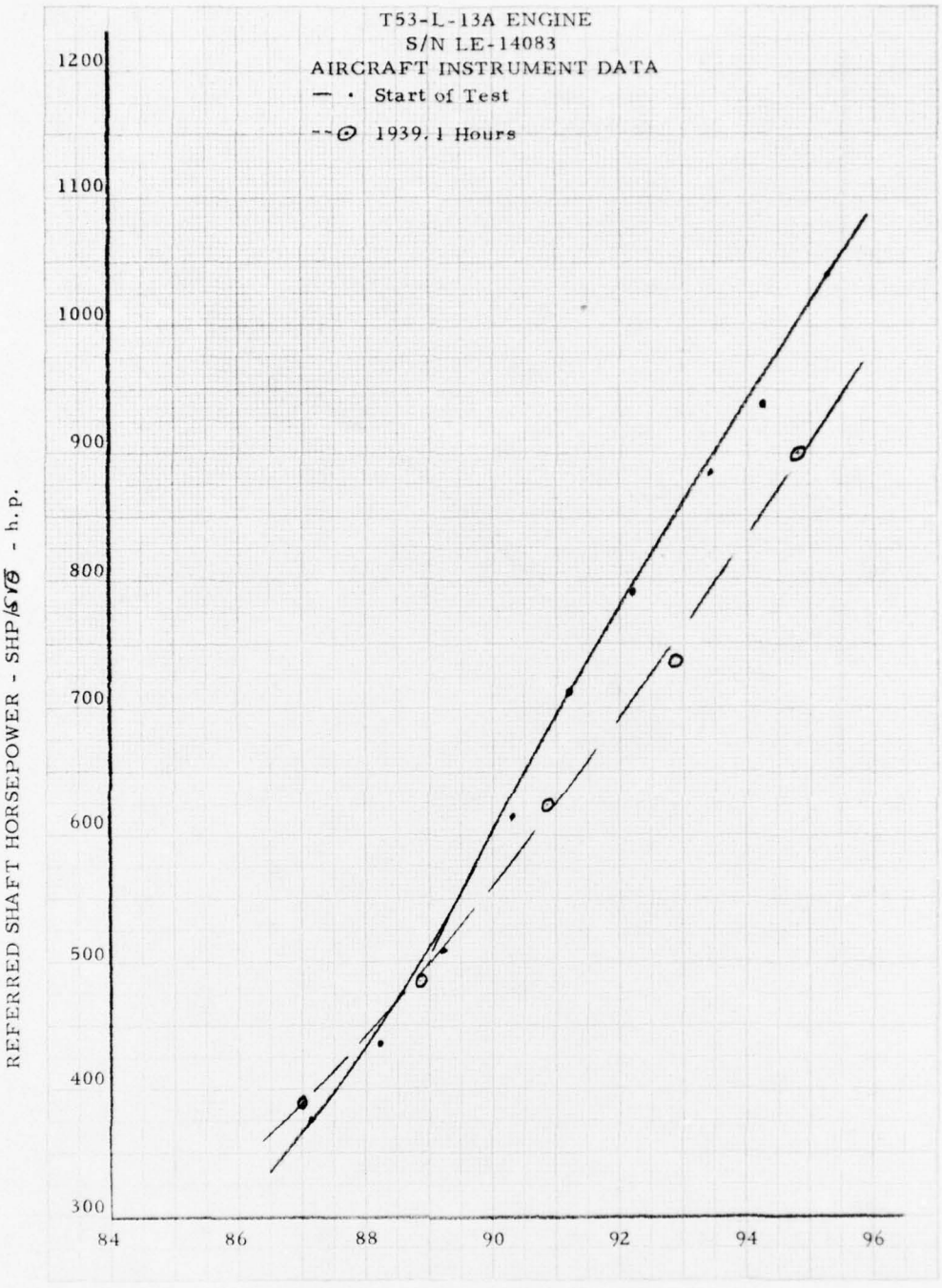
T53-L-13A ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— · Start of Test
--⊙ 1939.1 Hours
REFERRED SHAFT HORSEPOWER - SHP/δ√θ - h.p.
1200
1100
1000
900
800
700
600
500
400
300
84
86
88
90
92
94
96
REFERRED GAS PRODUCER SPEED - N1/√θ - % RPM

Figure 48.

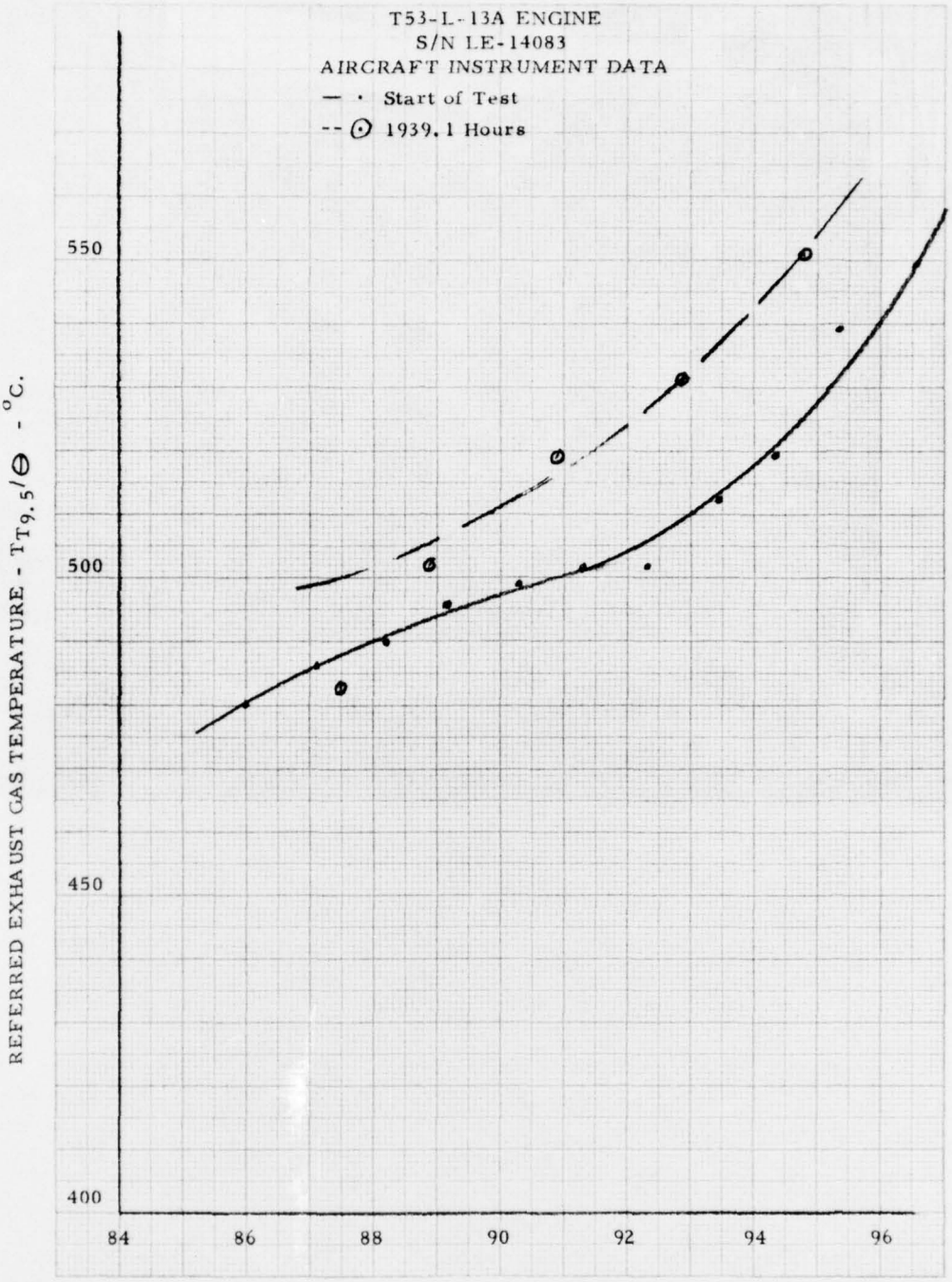
T53-L-13A ENGINE
S/N LE-14083
AIRCRAFT INSTRUMENT DATA
— · Start of Test
-- ⊙ 1939.1 Hours
550
500
450
400
84
86
88
90
92
94
96
REFERRED EXHAUST GAS TEMPERATURE - $T_{T9.5}/\Theta$ - °C.
REFERRED GAS PRODUCER SPEED - $N_1/\sqrt{\Theta}$ - % RPM

Figure 49.

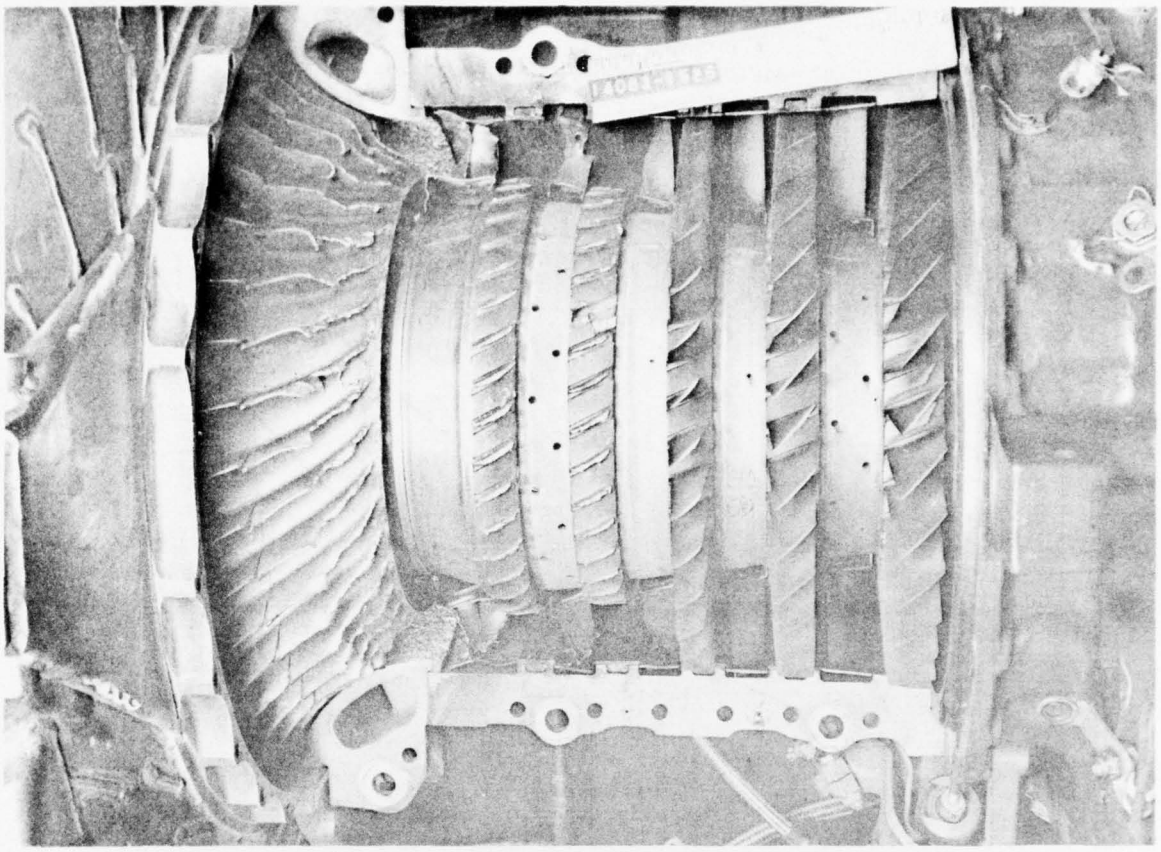

Figure 50.

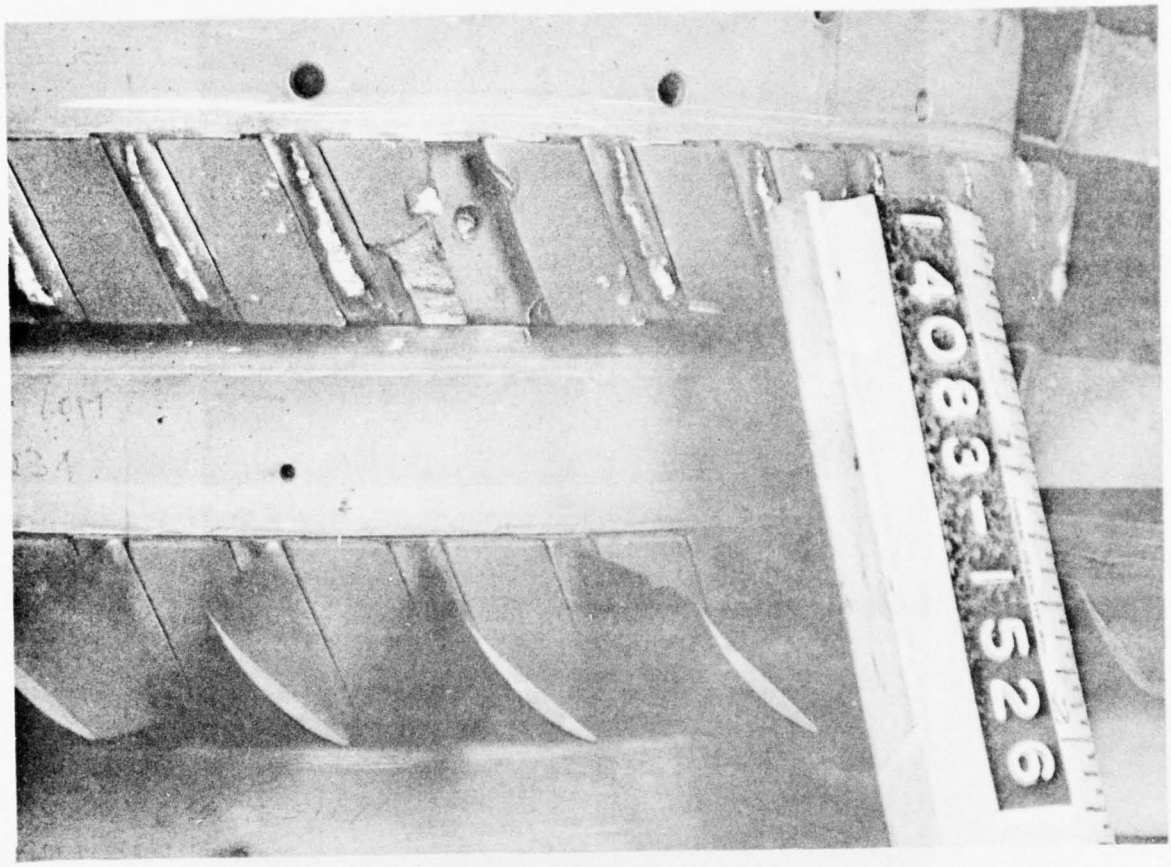

Figure 51.

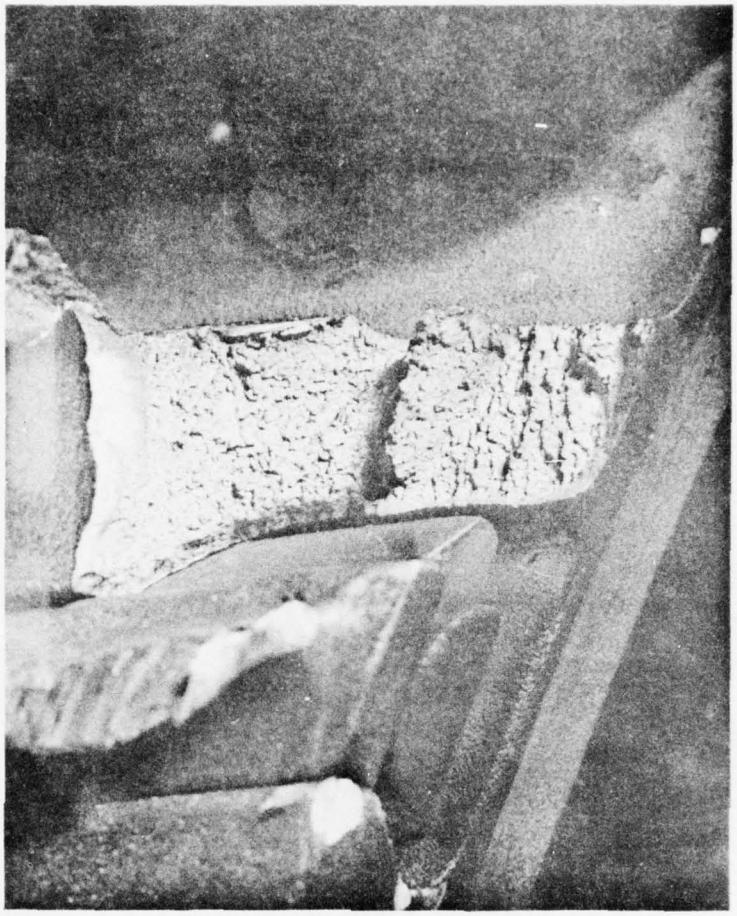

Figure 52.

RECOMMENDED CHANGES
TO TB 55-2800-200-30/1

Letter Report of Test of T53-L-13
Engine, S/N LE-14083,
USATECOM Project No. 4-6-0150-05

The following changes in damage limits are recommended on the basis of this test program:

1. First-Stage Gas-Producer Nozzle, P/N's 1-110-520-14, 1-110-520-19, and 1-110-520-21.

Add: Cracks up to 1/4 inch, which extend from the vane brazements at the trailing edge into the outer shroud, are allowable at no more than 15 vanes.

2. Second-Stage Gas-Producer Nozzle, P/N 1-120-000-06D.

Change: Axial cracks in parent metal of outer shroud emanating from vane leading edges that do not exceed 5/16 inch in length are acceptable on a maximum of 10 vanes. Axial cracks in parent metal that do not exceed 3/16 inch in length are acceptable on a maximum of 30 vanes. Converging or circumferential cracks are not permitted.

To read: Cracks in the outer shroud which extend axially from the vane leading edge are allowable at 40 vanes provided they do not extend over the edge onto the vertical face of the outer shroud. Of the 40 allowable, 10 may extend over the edge onto the vertical face of the outer shroud a distance of 1/4 inch from the vane leading edge. Converging or circumferential cracks are not permitted.

3. First-Stage Power-Turbine Nozzle, P/N 1-190-000-09C.

a. Change: Cracks in outer shroud brazements are acceptable in up to 15 vanes, provided that no more than four adjacent vanes are affected and the maximum crack length does not exceed 1/2 inch except that four brazements may contain cracks up to one inch long.

To read: All vanes may have brazement cracks in the outer shroud provided cracks do not exceed 1/2 inch in length.

INCLOSURE 2

b. Change: On outer shroud leading edge, three 1/4-inch radial cracks are allowed.

To read: All vanes may have axial cracks extending from brazement cracks at the vane leading edge in the outer shroud provided that no more than 10 such cracks extend onto the vertical face of the outer shroud more than 3/8 inch.

4. Exhaust Diffuser, P/N 1-150-240-01.

Add: Circumferential cracks up to 3/4 inch are allowed on two outer struts at the leading edge outboard end of the outer strut. These cracks may cross the radial weld which is on the outer strut.

LIST OF REFERENCES

Letter Report of Test of T53-L-13
Engine, S/N LE-14083,
USATECOM Project No. 4-6-0150-05

1. Letter, AMSTE-BG 4-6-0150-05, Headquarters, US Army Test and Evaluation Command, 8 February 1966, subject: "Test Directive, Product Improvement Test (Phase F), T53-L-13 Engine."

2. Test Plan, "Product Improvement Test (Phase F) T53-L-13 Engine," USATECOM Project No. 4-6-0150-05, US Army Aviation Test Board, 15 April 1966.

3. Technical Bulletin 55-2800-200-30/1, "T-53 Engine Inspection Guide, Aircraft Engine Models T53-L-3/3A/5/7/9/9A/11/11B/13," 26 April 1967, with Change 3, 1 April 1968.

4. Interim Report, "Product Improvement Test (Phase F) of T53-L-13 Engine," RDT&E Project No. _____, USATECOM Project No. 4-6-0150-05, US Army Aviation Test Board, 18 October 1967.

5. Message, UNCLAS AMSAV-EOT 8-1380, Commanding General, US Army Aviation Materiel Command, 28 August 1968, subject: "Test Report on T53-L-13 Engine, S/N LE-14083."